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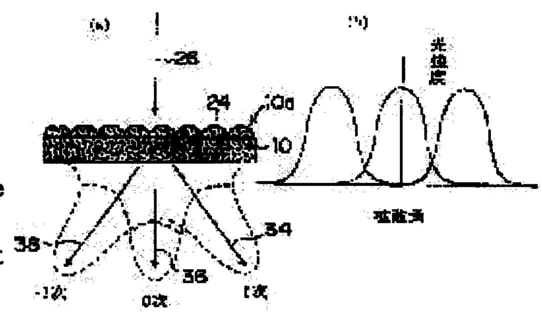
(54) OPTICAL ELEMENT, METHOD FOR MANUFACTURING OPTICAL ELEMENT, DUPLICATED PRODUCT OF OPTICAL ELEMENT AND METHOD FOR MANUFACTURING DUPLICATED PRODUCT OF OPTICAL ELEMENT

(57)Abstract:
PROBLEM TO BE SOLVED: To provide an optical element in which an excellent refraction effect or diffraction effect can be obtained by recesses and projections formed on the surface and a method for manufacturing the element, and to provide an optical element in which a light beam in an optional profile can be obtained by the refraction effect or diffraction effect and a method for manufacturing the optical element.
SOLUTION: A rugged pattern 24 functioning as lenticular lenses is formed on the surface 10a of an azopolymer carrier 10, and fine recesses and projections are formed on the surface of the rugged pattern 24. When incident light 26 enters the optical element through the face where the rugged pattern 24 is formed, diffused light divided in three directions (+1st order light 34, −1st order light 36 and 0-order light 38) is formed.



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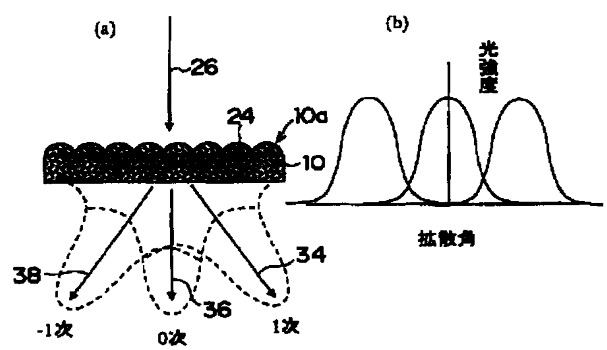
(54)【発明の名称】　光学素子、光学素子の製造方法、光学素子複製物、及び光学素子複製物の製造方法

(57)【要約】
【課題】表面に形成された凹凸により、優れた屈折効果または回折効果を得ることができる光学素子とその製造方法とを提供する。また、屈折効果及び回折効果により、任意の形状の光ビームを得ることができる光学素子及びその製造方法を提供する。
【解決手段】アゾポリマー担体１０の表面１０ａに、レンチキュラーレンズとして機能する凹凸２４を形成し、凹凸２４の表面に微細な凹凸を形成する。この光学素子に凹凸２４が形成された側から入射光２６が入射すると、３分岐の拡散光（プラス１次光３４、マイナス１次光３６、及び０次光３８）が生成される。



【特許請求の範囲】

【請求項１】アゾベンゼン骨格を有する高分子層を備え、
該高分子層の表面に屈折機能を有する凹凸が形成された光学素子。

【請求項２】アゾベンゼン骨格を有する高分子層を備え、
該高分子層の表面に回折機能を有する深さ１μm以上の凹凸が形成された光学素子。

【請求項３】アゾベンゼン骨格を有する高分子層を備え、
該高分子層の表面に屈折機能を有する第１凹凸が形成されると共に、該第１凹凸の表面に屈折機能または回折機能を有する第２凹凸が形成された光学素子。

【請求項４】屈折光学素子と、該屈折光学素子の表面に形成されたアゾベンゼン骨格を有する高分子層とを備え、
該高分子層の表面に屈折機能及び回折機能の少なくとも一方を有する凹凸が形成された光学素子。

【請求項５】アゾベンゼン骨格を有する高分子層を備え、
該高分子層の表面に屈折機能を有する第１凹凸が形成されると共に、該第１凹凸の表面に該第１凹凸より狭い間隔で第２凹凸が形成された光学素子。

【請求項６】屈折機能を有する第１凹凸を備えた屈折光学素子と、該第１凹凸の表面にアゾベンゼン骨格を有する高分子層とを備え、
該高分子層の表面に前記第１凹凸より狭い間隔で第２凹凸が形成された光学素子。

【請求項７】前記屈折機能を有する凹凸が５〜１００μmの間隔で形成された請求項１及び３〜６のいずれか１項に記載の光学素子。

【請求項８】前記回折機能を有する凹凸が０．２〜５μmの間隔で形成された請求項２〜４のいずれか１項に記載の光学素子。

【請求項９】前記高分子のガラス転移点が、室温より高温である請求項１〜８のいずれか１項に記載の光学素子。

【請求項１０】前記高分子のガラス転移点が、室温近傍である請求項１〜９のいずれか１項に記載の光学素子。

【請求項１１】前記高分子のガラス転移点が、２０℃〜５０℃の範囲である請求項１〜１０のいずれか１項に記載の光学素子。

【請求項１２】アゾベンゼン骨格を有する高分子層を備え、
該高分子のガラス転移点が室温より高温であり、
前記高分子層の表面に屈折機能及び回折機能の少なくとも一方を有する凹凸が形成された光学素子。

【請求項１３】アゾベンゼン骨格を有する高分子層を備え、
該高分子のガラス転移点が室温近傍であり、
前記高分子層の表面に屈折機能及び回折機能の少なくとも一方を有する凹凸が形成された光学素子。

【請求項１４】アゾベンゼン骨格を有する高分子層を備え、
該高分子のガラス転移点が２０℃〜５０℃の範囲であり、
前記高分子層の表面に屈折機能及び回折機能の少なくとも一方を有する凹凸が形成された光学素子。

【請求項１５】前記凹凸のうち屈折機能を有する部分に係る凹凸が５〜１００μmの間隔で形成された請求項１２〜１４のいずれか１項に記載の光学素子。

【請求項１６】前記凹凸のうち回折機能を有する部分に係る凹凸が０．２〜５μmの間隔で形成された請求項１２〜１５のいずれか１項に記載の光学素子。

【請求項１７】前記凹凸のうち回折機能を有する部分に係る凹凸が深さ１μm以上で形成された請求項１２〜１４及び１６のいずれか１項に記載の光学素子。

【請求項１８】前記凹凸は、前記高分子層の表面に形成され屈折機能を有する第１凹凸と、該第１凹凸の表面に形成され屈折機能または回折機能を有する第２凹凸とを備える請求項１２〜１４のいずれか１項に記載の光学素子。

【請求項１９】前記高分子層が屈折光学素子の表面に形成された請求項１２〜１８のいずれか１項に記載の光学素子。

【請求項２０】前記高分子層の内部にホログラムが記録された請求項１〜１９のいずれか１項に記載の光学素子。

【請求項２１】前記高分子層の厚さを１〜１０μmとした請求項１〜２０のいずれか１項に記載の光学素子。

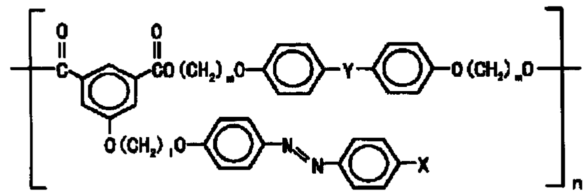
【請求項２２】前記高分子は、側鎖にアゾベンゼン骨格を含む請求項１〜２１のいずれか１項に記載の光学素子。

【請求項２３】前記高分子は、主鎖に芳香族炭化水素基を含む請求項１〜２２のいずれか１項に記載の光学素子。

【請求項２４】前記高分子は、下記一般式（１）で表されるポリエステルである請求項１〜２３のいずれか１項に記載の光学素子。

【化１】

一般式（１）



（式中、Ｘはシアノ基、メチル基、メトキシ基、またはニトロ基を示し、Ｙはエーテル結合、ケトン結合、またはスルホン結合による２価の連結基を示す。ｌおよびｍは２～１８の整数を示し、ｎは５～５００の整数を示す。）

【請求項２５】請求項１～２４のいずれか１項に記載の光学素子を製造する光学素子の製造方法であって、
前記高分子層の表面に所定の強度分布を有する光を照射し、該強度分布に応じた凹凸を形成して、
光学素子を製造する光学素子の製造方法。

【請求項２６】前記光が円偏光である請求項２５に記載の光学素子の製造方法。

【請求項２７】前記所定の強度分布が、計算機ホログラムまたはキノフォームに対応した強度分布である請求項２５または２６に記載の光学素子の製造方法。

【請求項２８】前記所定の強度分布が、拡散体から得られたスペックルパターンに対応した強度分布である請求項２５または２６に記載の光学素子の製造方法。

【請求項２９】請求項１～２４のいずれか１項に記載の光学素子を製造する光学素子の製造方法であって、
前記高分子層の表面に物体光及び参照光を照射し、該物体光及び参照光の干渉光による強度分布に応じた凹凸を形成して、
光学素子を製造する光学素子の製造方法。

【請求項３０】前記物体光と参照光は互いに逆周りの円偏光である請求項２９に記載の光学素子の製造方法。

【請求項３１】請求項１～２４のいずれか１項に記載の光学素子の複製物を製造する光学素子複製物の製造方法であって、
前記光学素子の表面に形成された凹凸を利用して、該凹凸を転写するためのスタンパを作製し、
該スタンパを用いた熱圧着または射出成形により、樹脂材料の表面に前記凹凸と同じ形状の凹凸を形成して、
前記光学素子の複製物を製造する光学素子複製物の製造方法。

【請求項３２】請求項１～２４のいずれか１項に記載の光学素子の表面に形成された凹凸が転写された光学素子複製物。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、光学素子、光学素子の製造方法、光学素子複製物、及び光学素子複製物の製造方法に関し、特に、アゾベンゼン骨格を有する高分子層を備え、屈折機能及び回折機能の少なくとも一方を有する光学素子、その光学素子の製造方法、その光学素子の複製物、及び光学素子複製物の製造方法に関する。

【０００２】

【従来の技術】従来、光学機器の分野では、凸レンズ、凹レンズ、プリズム等の光の屈折を利用した光学素子（屈折光学素子）が広く用いられてきた。最近では、微細加工技術の発展によりマイクロレンズアレイやレンチキュラーレンズ等の作製も可能となり、照明から光通信まで多様な用途において屈折光学素子が使用されている。

【０００３】例えば、特開平１０－２８２３７１号公報には、レンチキュラーレンズを備えた光データバスとこの光データバスを用いた信号処理装置が開示されている。この光データバス１０は、図３５（ａ）及び（ｂ）に示すように、信号光入射部１１の一方の端縁１１ａに、入射した信号光１５を光データバス１０内部に拡散させる、端縁１１ａに沿って配列された複数のシリンドリカル面（レンチキュラーレンズ）１２を形成している。光データバス１０に入射された信号光１５は、シリンドリカル面１２が複数配列されてなる拡散手段により信号光出射部１４側の端縁１４ａの全面にわたって拡散されるので、信号光のうち光伝送層１３の外に出て行く信号光が最小限に抑えられる。これにより信号光１５の伝送効率が高くなり、信号光出射部１４側の端縁１４ａにおける出射量のばらつきが少なくなる。このため、光データバス１０を用いた信号処理装置では、低消費電量化を図ることができる。

【０００４】

【発明が解決しようとする課題】しかしながら、レンズ等の屈折光学素子は、比較的単純な集光や光拡散の機能しか備えていない。例えば、上述の光データバスにおいては、単に信号光をレンチキュラーレンズにより拡散させているだけである。これに対し、屈折光学素子の代わりに光の回折を利用した回折光学素子やホログラムを利用した回折光学素子であるHolographic Optical Element（ＨＯＥ）を用いた場合には、複雑な光波を生成することができる。

【０００５】例えば、上記の光データバス１０において、図３５（ｃ）に示すように、信号光入射部１１の一方の端縁１１ａに、レンチキュラーレンズの代わりに回

折光学素子として拡散板２０を配置すると、光データバス１０に入射された信号光１５は、拡散板２０により回折され、信号光出射部１４側の端縁１４ａに設けられた所定の出力ポート（例えば、出力ポート１４ｂ、１４ｃ）に集光するように、分岐されると共に拡散される。

【０００６】この通り、回折光学素子によれば、入射波面を任意に設計した波面に変換することができる。また、回折光学素子は、屈折型レンズと逆の分散値を有し、実質的には厚みを持たないので光学系がコンパクトになるなど、屈折光学素子には無い利点を備えている。その一方、光の回折を利用するために、屈折光学素子と比べて本質的にアライメントの制約が大きい、波長分散が大きい、０次光の発生により回折効率が低下する等の問題点がある。

【０００７】また、ホログラムを利用した回折光学素子の作製方法としては、Photofabrication of surfaces for holograms, Sukant Tripathy, Dong-Yu Kim, Lian Li, and Jayant Kumar, CHEMTECH MAY (1998) pp. 34-40.に記載されているように、アゾベンゼン骨格を有する高分子（アゾポリマー）からなる記録媒体を用い、この記録媒体にホログラムを記録することで、媒体表面に微細な凹凸が誘起された表面レリーフホログラムを形成する方法が知られている。

【０００８】具体的には、アゾポリマーに感度のある波長のレーザ光源を用い、二光波を干渉させて、記録媒体の表面にサブミクロンピッチの表面レリーフホログラムを形成する。通常の半導体プロセスを利用するＨＯＥ作製過程は、パターン設計、露光、現像を複数回繰り返すため多くの工程を必要とするが、上記の方法では多くの工程が省略でき、製造コストを大幅に低減することができる。また、形成される表面レリーフホログラムのレリーフ深さは、露光エネルギーに比例して増加するので、緩やかに凹凸が変化した理想的な回折光学素子の作製が可能である。

【０００９】しかしながら、通常、上記の方法で得られるレリーフ深さは数１００ｎｍ程度であり、表面レリーフホログラムを形成して回折光学素子として使用する場合には、十分なレリーフ深さが得られず、回折されない０次光が発生して回折効率が低下するという実用上の問題が発生する。

【００１０】以上述べた通り、ＨＯＥを含む回折光学素子には、設計の自由度が大きいという利点があるが、光の回折を利用するために本質的にアライメントの制約が大きく、波長分散が大きい等の問題がある。一方、レンズなどの屈折光学素子には、設計の自由度は小さいが、アライメントの制約は少なく、波長分散は小さく、０次光による問題は発生しないという利点（屈折光学素子のロバスト性）がある。

【００１１】本発明は上記の問題点に鑑みなされたものであり、本発明の第１の目的は、表面に形成された凹凸により、優れた屈折効果または回折効果を得ることができる光学素子を提供することにある。本発明の第２の目的は、屈折効果及び回折効果により、任意の形状の光ビームを得ることができる光学素子を提供することにある。本発明の第３の目的は、表面に十分な深さの凹凸（レリーフ構造）を形成することにより、設計の自由度が向上すると共に、優れた屈折効果及び／または優れた回折効果を得ることができる光学素子を提供することにある。

【００１２】本発明の第４の目的は、任意の光パターンを照射して表面に所望形状の凹凸を誘起することにより、表面に凹凸が形成された光学素子を簡便且つ安価に製造することができる光学素子の製造方法を提供することにある。本発明の第５の目的は、表面に凹凸が形成された光学素子を用いて、同じ表面形状の光学素子を容易に複製でき、大量生産に好適な光学素子複製物の製造方法とその方法により得られた光学素子複製物とを提供することにある。

【００１３】

【課題を解決するための手段】上記の第１の目的を達成するために、請求項１に記載の光学素子は、アゾベンゼン骨格を有する高分子層を備え、該高分子層の表面に屈折機能を有する凹凸が形成されたことを特徴とする。この光学素子では、高分子層の表面に形成された凹凸により屈折効果を得ることができる。また、回折効率は十分な凹凸深さが得られなければ低下するが、この光学素子では、凹凸深さに拘らず凹凸間隔を最適化することにより、優れた屈折効果を得ることができる。

【００１４】上記の第１の目的を達成するために、請求項２に記載の光学素子は、アゾベンゼン骨格を有する高分子層を備え、該高分子層の表面に回折機能を有する深さ１μm以上の凹凸が形成されたことを特徴とする。この光学素子では、高分子層の表面に形成された深さ１μm以上の凹凸により回折効率が低下することなく、優れた回折効果を得ることができる。

【００１５】上記の第１または第２の目的を達成するために、請求項３に記載の光学素子は、アゾベンゼン骨格を有する高分子層を備え、該高分子層の表面に屈折機能を有する第１凹凸が形成されると共に、該第１凹凸の表面に屈折機能または回折機能を有する第２凹凸が形成されたことを特徴とする。この光学素子では、高分子層の表面に形成された第１凹凸により屈折効果が得られると共に、第１凹凸の表面に形成された第２凹凸により屈折効果または回折効果を得ることができる。

【００１６】即ち、第１凹凸による屈折効果に加えて、第２凹凸による屈折効果を得ることにより、優れた屈折効果を得ることができる。また、第１凹凸による屈折効果に加えて、第２凹凸による回折効果を得る場合には、任意の形状の光ビームを得ることができる。

【００１７】上記の第１または第２の目的を達成するた

めに、請求項４に記載の光学素子は、屈折光学素子と、該屈折光学素子の表面に形成されたアゾベンゼン骨格を有する高分子層とを備え、該高分子層の表面に屈折機能及び回折機能の少なくとも一方を有する凹凸が形成されたことを特徴とする。この光学素子では、屈折光学素子により屈折効果が得られると共に、高分子層の表面に形成された凹凸により屈折効果及び回折効果の少なくとも一方を得ることができる。

【００１８】即ち、屈折光学素子による屈折効果に加えて、凹凸による屈折効果を得ることにより、優れた屈折効果を得ることができる。また、屈折光学素子による屈折効果に加えて、凹凸による回折効果を得る場合には、任意の形状の光ビームを得ることができる。

【００１９】上記の第１または第２の目的を達成するために、請求項５に記載の光学素子は、アゾベンゼン骨格を有する高分子層を備え、該高分子層の表面に屈折機能を有する第１凹凸が形成されると共に、該第１凹凸の表面に該第１凹凸より狭い間隔で第２凹凸が形成されたことを特徴とする。この光学素子では、高分子層の表面に形成された第１凹凸により屈折効果が得られると共に、この第１凹凸の表面に形成された第２凹凸の形状に応じて、屈折効果及び回折効果の少なくとも一方を得ることができる。

【００２０】上記の第１または第２の目的を達成するために、請求項６に記載の光学素子は、屈折機能を有する第１凹凸を備えた屈折光学素子と、該第１凹凸の表面にアゾベンゼン骨格を有する高分子層とを備え、該高分子層の表面に前記第１凹凸より狭い間隔で第２凹凸が形成されたことを特徴とする。この光学素子では、屈折光学素子の表面に在る第１凹凸により屈折効果が得られると共に、この第１凹凸の表面に形成された第２凹凸の形状に応じて、屈折効果及び回折効果の少なくとも一方を得ることができる。

【００２１】上記の光学素子において、屈折機能を有する凹凸が５～１００μｍの間隔で形成されることが好ましく、回折機能を有する凹凸が０．２～５μｍの間隔で形成されることが好ましい。

【００２２】上記の光学素子において、高分子のガラス転移点は、室温より高温、室温近傍、または２０℃～５０℃の範囲のいずれかであることが好ましい。

【００２３】上記の第３の目的を達成するために、請求項１２に記載の光学素子は、アゾベンゼン骨格を有する高分子層を備え、該高分子のガラス転移点が室温より高温であり、前記高分子層の表面に屈折機能及び回折機能の少なくとも一方を有する凹凸が形成されたことを特徴とする。高分子のガラス転移点が室温より高温である場合には、光を照射して凹凸を誘起する場合に、十分な深さの凹凸を誘起できると共に、誘起された凹凸を安定に維持することができる。この結果、光学素子の表面に十分な深さの凹凸を容易且つ安定に形成することができ、設計の自由度が向上すると共に、優れた屈折効果及び／または優れた回折効果を得ることができる。

【００２４】また、上記の第３の目的を達成するために、請求項１３に記載の光学素子は、アゾベンゼン骨格を有する高分子層を備え、該高分子のガラス転移点が室温近傍であり、前記高分子層の表面に屈折機能及び回折機能の少なくとも一方を有する凹凸が形成されたことを特徴とする。高分子のガラス転移点が室温近傍である場合には、光を照射して凹凸を誘起する場合に、十分な深さの凹凸を誘起できる。この結果、光学素子の表面に十分な深さの凹凸を容易に形成することができ、設計の自由度が向上すると共に、優れた屈折効果及び／または優れた回折効果を得ることができる。

【００２５】また、上記の第３の目的を達成するために、請求項１４に記載の光学素子は、アゾベンゼン骨格を有する高分子層を備え、該高分子のガラス転移点が２０℃～５０℃の範囲であり、前記高分子層の表面に屈折機能及び回折機能の少なくとも一方を有する凹凸が形成されたことを特徴とする。高分子のガラス転移点が２０℃～５０℃の範囲である場合には、光を照射して凹凸を誘起する場合に、十分な深さの凹凸を誘起できると共に、誘起された凹凸を安定に維持することができる。この結果、光学素子の表面に十分な深さの凹凸を容易且つ安定に形成することができ、設計の自由度が向上すると共に、優れた屈折効果及び／または優れた回折効果を得ることができる。

【００２６】請求項１２～１４に記載の光学素子において、高分子層の表面に形成される凹凸のうち屈折機能を有する部分に係る凹凸は、５～１００μｍの間隔で形成することができる。また、高分子層の表面に形成される凹凸のうち回折機能を有する部分に係る凹凸は、０．２～５μｍの間隔で形成することができ、回折機能を有する部分に係る凹凸は、深さ１μｍ以上で形成されることが好ましい。更に、高分子層の表面に形成される凹凸として、高分子層の表面に形成され屈折機能を有する第１凹凸と、該第１凹凸の表面に形成され屈折機能または回折機能を有する第２凹凸とを備えることができる。また、高分子層が屈折光学素子の表面に形成されていてもよい。

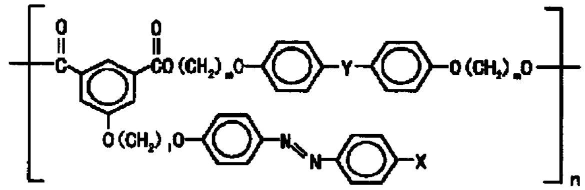
【００２７】上記の光学素子において、高分子層の内部にホログラムが記録されていてもよい。この場合は、内部に記録されたホログラムにより回折機能を得ることができる。

【００２８】高分子層の厚さは、より深い凹凸の形成を可能とするために、１～１０μｍとするのが好ましい。また、高分子は、側鎖にアゾベンゼン骨格を有するものが好ましく、主鎖に芳香族炭化水素基を含むものがより好ましい。これらの高分子の中でも、下記一般式（１）で表されるポリエステルが特に好ましい。

【００２９】

【化２】

一般式（１）



【００３０】（式中、Ｘはシアノ基、メチル基、メトキシ基、またはニトロ基を示し、Ｙはエーテル結合、ケトン結合、またはスルホン結合による２価の連結基を示す。ｌおよびｍは２～１８の整数を示し、ｎは５～５００の整数を示す。）上記の第４の目的を達成するために、請求項２５に記載の発明は、本発明の光学素子を製造する光学素子の製造方法であって、光学素子に設けられた高分子層の表面に所定の強度分布を有する光を照射し、該強度分布に応じた凹凸を形成して、光学素子を製造することを特徴とする。この場合、照射する光が円偏光であることが好ましい。また、所定の強度分布を、計算機ホログラムまたはキノフォームに対応した強度分布や、拡散体から得られたスペックルパターンに対応した強度分布とすることができる。

【００３１】この製造方法では、計算機ホログラムまたはキノフォームに対応した強度分布を有する光や、拡散体から得られたスペックルパターンに対応した強度分布を有する光など、任意の光パターンを照射することにより、高分子層の表面に所望形状の凹凸を形成することができ、高分子層の表面に凹凸が形成された光学素子を簡便且つ安価に製造することができる。

【００３２】また、上記の第４の目的を達成するために、請求項２９に記載の発明は、本発明の光学素子を製造する光学素子の製造方法であって、光学素子に設けられた高分子層の表面に物体光及び参照光を照射し、該物体光及び参照光の干渉光による強度分布に応じた凹凸を形成して、光学素子を製造することを特徴とする。この場合、物体光と参照光は互いに逆周りの円偏光であることが好ましい。

【００３３】この製造方法では、例えば光の干渉縞など、任意の光パターンを照射することにより、高分子層の表面に所望形状の凹凸を形成することができ、高分子層の表面に凹凸が形成された光学素子を簡便且つ安価に製造することができる。

【００３４】上記の第５の目的を達成するために、請求項３１に記載の光学素子複製物の製造方法は、本発明の光学素子の複製物を製造する光学素子複製物の製造方法であって、前記光学素子の表面に形成された凹凸を利用して、該凹凸を転写するためのスタンパを作製し、該スタンパを用いた熱圧着または射出成形により、樹脂材料の表面に前記凹凸と同じ形状の凹凸を形成して、前記光学素子の複製物を製造することを特徴とする。

【００３５】また、上記の第５の目的を達成するために、請求項３２に記載の光学素子複製物は、本発明の光学素子の表面に形成された凹凸が転写されたものであることを特徴とする。

【００３６】上記の光学素子複製物の製造方法では、例えば、本発明の光学素子を用いてマスタリングを行ってメタルマスタを作製し、このメタルマスタに基づいてスタンパを作製する等、本発明の光学素子の表面に形成された凹凸を利用して、この凹凸を転写するためのスタンパを作製することができる。そして、このスタンパを用いた熱圧着または射出成形など大量生産に適した方法により、樹脂材料の表面に光学素子の表面に形成された凹凸と同じ形状の凹凸を形成して、同じ表面形状の光学素子を容易に複製することができる。このため、複雑な表面形状の光学素子も容易に大量生産することができる。また、得られた光学素子複製物は、本発明の光学素子と同様に、優れた屈折効果及び／または優れた回折効果を発揮する。

【００３７】

【発明の実施の形態】以下、図面を参照して本発明の実施の形態について説明する。

〔高分子担体または高分子層の材料〕本発明の光学素子に使用する高分子材料は、アゾベンゼン骨格を有する高分子（以下、「アゾポリマー」と称する）である。このアゾベンゼン骨格は、トランス－シス－トランスの光異性化サイクルを示す。

【００３８】本発明においては、これらアゾポリマーの中でも、ガラス転移点Ｔｇが室温近傍、好ましくは室温より少し高温のアゾポリマーが特に好ましい。従来、Photofabrication of surfaces for holograms, Sukant Tripathy, Dong-Yu Kim, LianLi, and Jayant Kumar, CHEMTECH MAY (1998) pp. 34-40. に記載されているように、表面レリーフ形成には、ガラス転移点Ｔｇが１００℃以上のアゾポリマーが使用されていたが、本発明者等は、ガラス転移点Ｔｇが室温近傍のアゾポリマーを記録媒体に用いることで、深いレリーフ構造が容易且つ安定に得られることを見出し、光学素子の設計の自由度を大幅に向上させた。

【００３９】また、分子構造の観点から、側鎖にアゾベンゼン骨格を含む高分子が好ましく、主鎖に芳香族炭化

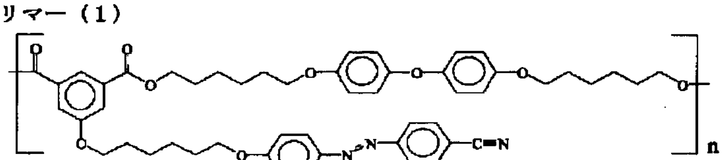
水素基を含む高分子がより好ましい。これらの中でも、上記一般式（１）で表されるポリエステルが特に好ましい。

【００４０】本発明で使用することができるアゾポリマ＊ーの具体例を以下に示す。

【００４１】

【化３】

アゾポリマー（１）



【００４２】上記の側鎖にシアノアゾベンゼンを持つポリエステル（アゾポリマー（１））は、M.Satoらの”Synthesis and properties of polyesters having cyanoazobenzene units in the side chain", Macromol. Rapid Commun. 15, 21-29 (1994)に報告されており、この文献に記載されている方法により合成することができる。次に、このアゾポリマー（１）の合成手順を説明する。

【００４３】（4－ヒドロキシ－4'－シアノアゾベンゼンの合成）　4－アミノベンゾニトリル２モル（２３６．３ｇ）、ＨＣｌ（１２Ｎ）６００ミリリットル、及び純水６００ミリリットルを氷浴中で攪拌しながら、$NaNO_2$水溶液（$NaNO_2$ １５０ｇ、純水７５０ミリリットル）を滴下した（ステップ１）。フェノール２モル（１９１．８ｇ）とＫＯＨ２モル（１１２．３ｇ）を約２リットルの純水にすばやく溶解し、ステップ１の生成物を滴下して反応させた。反応終了後、生成物を吸引ろ過によりろ取した後、純水で洗浄して減圧乾燥した。得られた生成物をメタノールで再結晶させ、４－ヒドロキシ－4'－シアノアゾベンゼン１．３モル（２９２．３ｇ、収率６５．５％）の結晶を得た。

【００４４】（４－（６－ブロモヘキシルオキシ）－4'－シアノアゾベンゼンの合成）４－ヒドロキシ－4'－シアノアゾベンゼン０．２モル（４４．６ｇ）、１，６－ジブロモヘキサン２モル（４８８．１ｇ）、K_2CO_3 １．４５モル（２００．４ｇ）、及びアセトン８００ミリリットルを２リットルの三つ口フラスコに入れ、ウォータバスを用いて２０時間還流し反応させた。室温まで冷却した後、副生成物と過剰のK_2CO_3をろ過して取り除いた。得られたろ液をロータリエバポレータを用いて約１／２程度まで濃縮した後に冷凍庫に放置して結晶化させた。析出した結晶を吸引ろ過によりろ取した後、ｎ－ヘキサンで洗浄して減圧乾燥した（０．１１７モル（４５．３ｇ、収率５８．６％））。更に、得られた粗結晶をエタノールで再結晶させ、４－（６－ブロモヘキシルオキシ）－4'－シアノアゾベンゼン０．０９４モル（３６．３ｇ、収率４７．０％）を得た。

【００４５】（５－ヒドロキシイソフタル酸ジエチルエステルの合成）　５－ヒドロキシイソフタル酸１モル（１８２．４ｇ）、エタノール１５００ミリリットル、及び濃硫酸１０ミリリットルを２リットルの三つ口フラスコに入れ、ウォータバスを用いて２４時間還流し反応させた。反応液をロータリエバポレータを用いて濃縮し、濃縮液を$NaHCO_3$水溶液に注いだ後、生成物をろ取し、減圧乾燥して、５－ヒドロキシイソフタル酸ジエチルエステル０．０９６モル（２２８．８ｇ、収率９６．０％）を得た。更に、得られた生成物をエタノールで再結晶させ、加熱（５０～６０℃）下で減圧乾燥した。

【００４６】（側鎖部モノマー：５－（４－シアノベンゼンアゾフェノキシヘキシルオキシ）－イソフタル酸エチルエステルの合成）　４－（６－ブロモヘキシルオキシ）－4'－シアノアゾベンゼン０．０８モル（３０．９ｇ）、５－ヒドロキシイソフタル酸ジエチルエステル０．０８モル、K_2CO_3 ０．１２モル（１６．５８ｇ）、及びアセトン４００ミリリットルを１リットルの三つ口フラスコに入れ、ウォータバスを用いて２４時間還流し反応させた。放冷後、反応液を約４リットルの純水に注ぎ、沈殿物をろ過して取り出し、減圧乾燥した（０．０７１モル（３８．８ｇ、収率８９．２％））。その後アセトンで再結晶させ、側鎖部モノマーとなる５－（４－シアノベンゼンアゾフェノキシヘキシルオキシ）－イソフタル酸エチルエステル０．０５８モル（３１．４ｇ、収率７２．２％）の結晶を得た。得られた結晶の融点は９９．０℃であり、３６４．２ｎｍに吸収ピークを有していた。

【００４７】側鎖部モノマーの同定は、ＦＴＩＲスペクトルと^{1}Ｈ－ＮＭＲとによって行った。ＦＴＩＲの測定結果を次に示す。

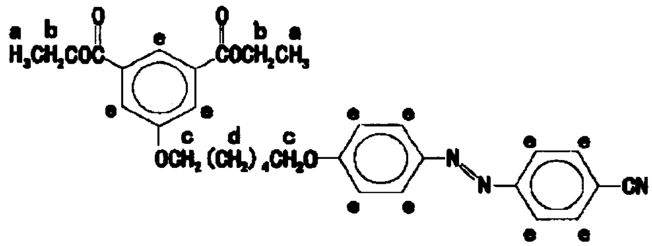
ＦＴＩＲ（KBr）：2947.7cm^{-1}（CH伸縮），2227.4cm^{-1}（CN），1713.4cm^{-1}（エステルC=O），1599.7cm^{-1}（C=C），1580cm^{-1}（N=N），1244.8cm^{-1}（C-O-C）

また、下記表１に^{1}Ｈ－ＮＭＲスペクトル分析の結果を示す。

【００４８】

【表１】

側鎖部モノマー^{1}H NMR スペクトルの化学シフト（$CDCl_3$）



diethyl-5-(4-cyanobenzeneazophenoxyhexyloxy)isophthalate
(543.61)

水素の位置	a	b	c	d	e		
δ (ppm)	1.40 (6H)	4.39 (4H)	4.07 (4H)	1.58～1.88 (8H)	7.00～7.03 (2H)	7.73～7.79 (5H)	7.91～7.94 (4H)

【００４９】（主鎖部モノマー：ビス（４－ヒドロヘキシルオキシフェニル）エーテルの合成）　４，４’－ジヒドロキシジフェニルエーテル０．３モル（６０．６６ｇ）、６－クロロ－１－ヘキサノール０．６６モル（９０．１６ｇ）、$K_2CO_3$０．７モル（９７ｇ）、及びＮ，Ｎ－ジメチルホルムアミド２５０ミリリットルを混合し、オイルバスを用いて１６０℃に加熱し２４時間反応させた。その後、反応液を少量の塩酸を含む水に注いで、生成物を吸引ろ過によりろ取し、減圧乾燥して、ビス（４－ヒドロヘキシルオキシフェニル）エーテルを得た。更に、得られた生成物を水－Ｎ，Ｎ－ジメチルホルムアミド系混合溶剤より再結晶させて、ビス（４－ヒドロヘキシルオキシフェニル）エーテルの結晶がほぼ定量＊＊的に得られた。得られた結晶の融点は１１９℃であった。

【００５０】主鎖部モノマーの同定は、ＦＴＩＲスペクトルと^{1}Ｈ－ＮＭＲとによって行った。ＦＴＩＲの測定結果を次に示す。

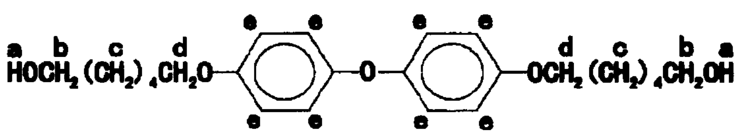
ＦＴＩＲ（KBr、JASCO FT/IR-230）：3312.1cm^{-1}（OH），2936.1cm^{-1}（CH伸縮），1505.2cm^{-1}（芳香族），1241.9cm^{-1}（C-O-C）

また、下記表２に^{1}Ｈ－ＮＭＲスペクトル分析の結果を示す。

【００５１】

【表２】

主鎖部モノマー^{1}H NMR スペクトルの化学シフト（$CDCl_3$）



bis(4-hydrohexyloxyphenyl)ether
(402.52)

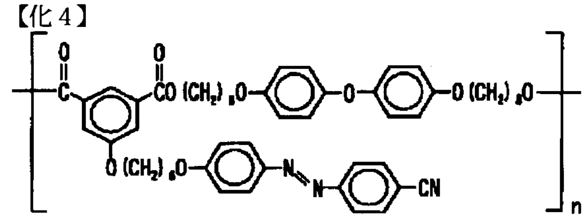
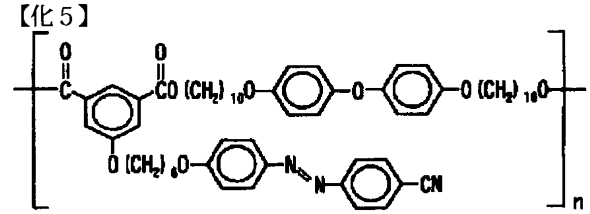
水素の位置	a	b	c	d	E
δ (ppm)	1.30 (2H)	3.67 (4H)	1.44～1.82 (16H)	3.93 (4H)	6.82～6.92 (8H)

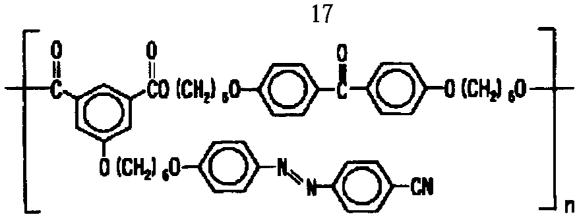
【００５２】（アゾベンゼンを側鎖に持つポリエステルの溶融重縮合）　側鎖部モノマー：５－（４－シアノベンゼンアゾフェノキシヘキシノキシ）－イソフタル酸エチルエステル０．０１モル（５．４３６１ｇ）、主鎖部モノマー：ビス（４－ヒドロヘキシルオキシフェニル）エーテル０．０１モル（４．０２５３ｇ）、及び無水酢酸亜鉛０．１ｇを３００ミリリットルの三つ口フラスコに入れ、窒素雰囲気下で、次の１）～４）のステップに従い反応させた。

１）約１６０℃で２時間反応

２）１０Ｔｏｒｒ（１．３３×１０^{3}Ｐａ）に減圧して２０分反応

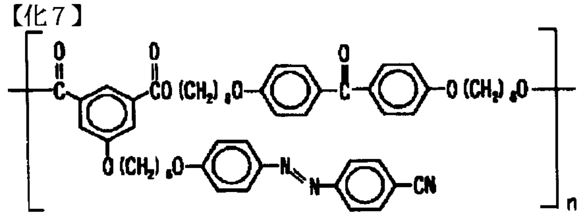
３）３０分かけて１８０℃、２～５Ｔｏｒｒ（０．２７×１０^{3}～０．６７×１０^{3}Ｐａ）に昇温・減圧

４）１８０℃、２～５Ｔｏｒｒ（０．２７×１０^3～０．６７×１０^{3}Ｐａ）で２時間反応
上記反応終了後、反応液をクロロホルムに溶解させてメタノール中に注いだ。沈殿物をろ過して取り出し、純水で加熱洗浄した後にメタノールで加熱洗浄し、減圧乾燥して、シアノアゾベンゼンを側鎖に持つポリエステルをほぼ定量的に得た。
【００５３】図１に上記方法で合成したアゾポリマー（１）のＤＳＣ（示差走査熱量計）曲線を示す。ガラス転移温度Ｔｇは３８℃、融点Ｔｍは６５℃であった。また、偏光顕微鏡観察によると、液晶相は存在せず固体状態において複屈折を有する高分子であった。
【００５４】次に、基板上にアゾポリマー（１）からなる高分子層を有する記録媒体を作成した。まず、上記方法で合成したアゾポリマー（１）をクロロホルムに０．８ｇ／ミリリットルの濃度で溶かし、洗浄したガラス基板上にスピンコートした（１０００ｒｐｍ，２０秒）。乾燥させた後、等方相になる温度まで加熱し、急冷して、アゾポリマー（１）からなる高分子層を形成した。偏光顕微鏡観察により形成された高分子層は等方的なアモルファス膜であることを確認した。また、触針式の表面粗さ計を用いて膜厚を測定したところ１．５μｍであった。
【００５５】この記録媒体を用いて表面レリーフホログラムを形成し、凹凸深さ（レリーフ深さ）と露光エネルギーとの関係を調べた。表面レリーフホログラムの形成に当っては、アルゴンイオンレーザの５１５ｎｍの発振線を用い、これを２光波に分岐して物体光及び参照光とすると共に、それぞれの偏光を互いに逆周りの円偏光とした。露光強度は０．５Ｗ／ｃｍ^{2}とした。形成されるグレーティングの間隔が１μｍ及び１０μｍの２通りとなるように２光波の交差角を調整して、レリーフ発達の様子を調べた。結果を図２に示す。
【００５６】図２から分かるように、露光エネルギーが増加するとレリーフ深さも増加した。また、間隔が１０μｍのグレーティングでは１μｍを超える深さの凹凸が形成できた。また、１μｍ間隔のグレーティングはそれより小さい０．２５μｍ程度の深さの凹凸が形成できた。
【００５７】このように、アゾポリマー（１）を用いた記録媒体では、従来より深いレリーフを誘起することができる。これはアゾポリマーのＴｇが室温近傍であるために、光照射による分子移動が容易に起こるためであると推測される。一方、室温より低いＴｇのアゾポリマーを用いると、光照射時には深いレリーフが誘起されるものの、光遮断後にその形状は維持されず、結果として深い凹凸を持つ光学素子は実現できない。従って、前記した通り、深いレリーフ構造が容易且つ安定に得られる点で、室温より少し高いＴｇ、好ましくは２０℃～５０℃の範囲のＴｇを示すアゾポリマーが本発明には好適である。
【００５８】次に、アゾポリマー（１）からなる高分子層の厚みを種々変えて記録媒体を複数作製し、各々の記録媒体について表面レリーフホログラムを形成して、レリーフ深さと露光エネルギーとの関係を調べたところ、アゾポリマーの厚みが１μｍ～１０μｍの範囲で、図２に示す場合と同様の大きさの凹凸が誘起されることが確認された。
【００５９】従来、厚み数百ｎｍのアゾポリマー層に数十から百μｍ程度の薄い膜で、凹凸が誘起された例は複数報告されているが、数μｍを超える厚いアゾポリマー層に深いレリーフ構造を誘起した例は報告されていない。本発明においては、アゾポリマー層の厚みを１μ～１０μｍと厚くした場合にも、効果的に数百ｎｍから数μｍの凹凸が誘起できることを明らかにした。即ち、上記した通り、適切なＴｇを有するアゾポリマーを記録媒体に用い、その厚みを比較的厚くしてホログラムを記録することで、非常に大きな表面レリーフ構造を生成できることを見出した。そして、これを光学素子に応用することにより、光学素子の設計の自由度を大幅に向上させることができた。
【００６０】本発明で使用することができる他のアゾポリマーの例（化学構造式とそのＴｇ）を以下に示す。これらのアゾポリマーは、アゾポリマー（１）と同様の方法で合成することができる。
【００６１】
【化４】

Tg=26.8℃, Tm=56.4℃
アゾポリマー(2)
【００６２】
【化５】

Tg=23.9℃, Tm=62.7℃
アゾポリマー(3)
【００６３】
【化６】



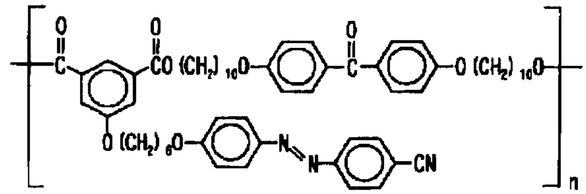
Tg=48.5℃, Tm=82.2℃
アゾポリマー（4）

【００６４】
【化７】



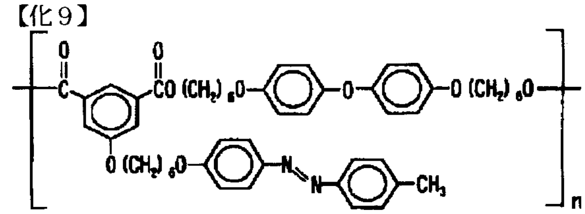
Tg=37.8℃, Tm=70.2℃
アゾポリマー（5）

【００６５】
【化８】



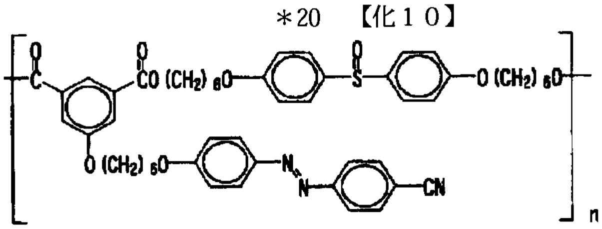
Tg=33.1℃, Tm=68.5℃
アゾポリマー（6）

【００６６】
【化９】



Tg=38.0℃
アゾポリマー（7）

【００６７】
【化１０】



アゾポリマー（8）

【００６８】上記の通り、例示したアゾポリマーのＴｇは２０℃から５０℃の範囲内にあり、レリーフ形成実験においても、アゾポリマー（１）と同様に深い凹凸を誘起できることが確認された。

【００６９】〔光学素子の形態〕本発明の光学素子は、図３（ａ）に示すように、アゾポリマー担体１０を備えるように構成することができる。なお、アゾポリマー担体は、アゾポリマー層のみで構成されている。アゾポリマー担体１０の表面１０ａには、屈折機能及び回折機能の少なくとも一方を有する所定形状の凹凸が形成されている。この凹凸は、記録媒体であるアゾポリマー担体１０の表面１０ａに、アゾポリマーの異性化を誘起する所定波長の光を所定の強度分布で照射することにより形成することができる。

【００７０】また、本発明の光学素子は、図３（ｂ）に示すように、ガラス基板やプラスチック基板等の基体１２と、この基体１２表面に形成されたアゾポリマー層１４とで構成されていてもよい。同様に、アゾポリマー層１４の表面１４ａには、屈折機能及び回折機能の少なくとも一方を有する所定形状の凹凸が形成されている。これらの凹凸は、この記録媒体のアゾポリマー層１４の表面１４ａに、アゾポリマーの異性化を誘起する所定波長の光を所定の強度分布で照射することにより、表面１４ａに所定形状の凹凸が形成される。

【００７１】上記のアゾポリマー層１４を備えた記録媒体は、例えば、アゾポリマーのクロロホルム溶液を、洗浄した基体１２上にキャストし乾燥することにより作製することができる。また、アゾポリマー溶液を基体１２上にスピンコートしてアゾポリマー層１４を形成してもよい。また、フィルム状の基体１２を用いる場合は、基体１２にアゾポリマー材料をホットプレスにより接着してアゾポリマー層１４を形成することもできる。

【００７２】上記の凹凸は、凹凸が形成される間隔（凹凸ピッチ）により、回折機能または屈折機能のいずれかを有する。回折機能について考察する場合、凹凸ピッチは格子間隔Λに相当する。入射光の波長をλ、媒体の屈折率をｎ、回折角（ホログラム記録の２光波交差角）をθとすると、格子間隔Λは下記式で与えられる。

【００７３】
【数１】

$$\Lambda = \frac{\lambda}{2n\sin\left\{\frac{1}{2}\sin^{-1}\left(\frac{1}{n}\sin\theta\right)\right\}}$$

【００７４】例えば、入射光の波長λ＝６００ｎｍ、媒体（アゾポリマー）の屈折率ｎ＝１．５とすると、格子間隔Λが５μｍ以上では回折角θは０°～７°と小さくなり、格子間隔Λが０．５μｍでは回折角θは９０°と大きくなる。即ち、凹凸ピッチがある程度広い場合には、回折角は小さく主に屈折による作用を有し、凹凸ピッチが狭くなるに従い、効果的な（回折角の大きい）回折機能を有するようになる。この通り、回折機能及び屈折機能の程度は、厳密には、入射光の波長λ、アゾポリマーの屈折率によっても多少変化するが、概略的には、凹凸ピッチが５～１００μｍの間隔で形成された場合に、その凹凸は屈折機能を有し、凹凸ピッチが０．２～５μｍの間隔で形成された場合に、その凹凸は回折機能を有すると考えて良い。また、上記の凹凸は、凹凸が形成される深さ（凹凸深さ）により、回折効率が変化する。前記の通り、凹凸深さが深くなるに従い０次光の発生が少なくなり、回折効率が向上する。

【００７５】なお、凹凸ピッチは隣接する凸部と凸部との間隔であり、凹凸深さは最大凸部と最大凹部とのギャップである。これら凹凸ピッチ及び凹凸深さは、ＡＦＭ（原子間力顕微鏡）による観察像から測定することができる。スペックルパターンのように凹凸ピッチが一定でない場合には、平均値または分散範囲を求めればよい。また、凹凸ピッチは上記の関係式に基づき、入射光の波長λ、アゾポリマーの屈折率ｎ、及び回折角θから求めることもできる。

【００７６】〔第１の実施の形態〕本実施の形態の光学素子は、アゾポリマー担体の表面に、レンチキュラーレンズとして機能する凹凸（第１凹凸）を形成し、この凹凸の表面にこの凹凸より狭い間隔で回折機能を有する凹凸（第２凹凸）を形成したものである。なお、レンチキュラーレンズは、図４（ａ）に示す構造を有している。

【００７７】まず、図５に示すように、空間光変調器１６によりレンチキュラーレンズの形状に対応した明暗（図６に示す光強度分布）を有する光波１８を生成し、この光波１８をレンズ２０及び２２によってアゾポリマー担体１０の表面１０ａに結像させる。これにより、図７（ａ）に示すように、レンチキュラーレンズの作用を持つようにアゾポリマー担体１０の表面１０ａに凹凸２４が形成される。

【００７８】図７（ａ）に示すように、この凹凸２４が形成されたアゾポリマー担体１０に、凹凸２４が形成された側から光（入射光）２６を入射させると、凹凸２４の屈折機能により拡散光２８を得ることができる。拡散光２８のビームプロファイルを図７（ｂ）に示す。図４（ｂ）に示すレンチキュラーレンズの拡散特性と略同じ拡散特性を有していることが分かる。

【００７９】次に、図８に示すように、アゾポリマー担体１０の凹凸２４が形成された表面１０ａに、レーザ光を二光波に分岐し、それぞれ物体光３０及び参照光３２として照射する。物体光３０及び参照光３２は互いに逆周りの円偏光とする。これにより効率よく表面レリーフホログラムが記録されて、アゾポリマー担体１０の凹凸２４の表面に微細な凹凸が形成される。

【００８０】表面レリーフホログラムを、入射光２６が入射した場合にプラス１次光３４、マイナス１次光３６、及び０次光３８を均等に回折するように設計しておくと、図９（ａ）に示すように、アゾポリマー担体１０に、凹凸２４が形成された側から入射光２６を入射させた場合に、３分岐の拡散光（プラス１次光３４、マイナス１次光３６、及び０次光３８）が生成され、図９（ｂ）に示す拡散角のビームを得ることができる。

【００８１】以上の通り、本実施の形態の光学素子では、アゾポリマー担体の表面に形成された凹凸によりレンチキュラーレンズと同じ屈折効果が得られると共に、この凹凸の表面に形成された微細な凹凸により回折効果を得ることができる。また、屈折効果及び回折効果の両方が得られるので、用途に応じて複雑なビームプロファイルを得ることができる。更に、任意の光パターンを照射して表面に所望形状の凹凸を誘起することにより、表面に凹凸を形成することができ、光学素子を簡便且つ安価に製造することができる。

【００８２】〔第２の実施の形態〕本実施の形態の光学素子は、基体として屈折光学素子であるレンチキュラーレンズを用いると共に、レンチキュラーレンズの凹凸（第１凹凸）面にアゾポリマー層を形成し、更にこのアゾポリマー層の表面にレンズの凹凸より狭い間隔で回折機能を有する凹凸（第２凹凸）を形成したものである。

【００８３】まず、図１０に示すように、石英のレンチキュラーレンズ１２Ａの凹凸面にアゾポリマーを均一にコートしてアゾポリマー層１４を形成する。アゾポリマー層１４はレンチキュラーレンズ１２Ａ表面の凹凸に沿って形成される。このレンチキュラーレンズは、図４（ａ）に示す構造を有しており、図４（ｂ）に示すように、入射光を半値全角が１０°となるように拡散させる。

【００８４】次に、図１１に示すように、アゾポリマー層１４の表面１４ａに、レーザ光を二光波に分岐し、それぞれ物体光３０及び参照光３２として照射する。物体光３０及び参照光３２は互いに逆周りの円偏光とする。これにより効率よく表面レリーフホログラムが記録されて、アゾポリマー層１４の表面１４ａに微細な凹凸が形成される。

【００８５】表面レリーフホログラムを、入射光２６が入射した場合にプラス１次光３４、マイナス１次光３６、及び０次光３８を均等に回折するように設計しておくと、図１２（ａ）に示すように、アゾポリマー層１４に、凹凸２４が形成された側から入射光２６を入射させた場合に、３分岐の拡散光（プラス１次光３４、マイナス１次光３６、及び０次光３８）が生成され、図１２

（ｂ）に示す拡散角のビームを得ることができる。

【００８６】以上の通り、本実施の形態の光学素子では、レンチキュラーレンズにより屈折効果が得られると共に、アゾポリマー層の表面に形成された微細な凹凸により回折効果を得ることができる。また、屈折効果及び回折効果の両方が得られるので、用途に応じて複雑なビームプロファイルを得ることができる。更に、任意の光パターンを照射して表面に所望形状の凹凸を誘起することにより、表面に凹凸を形成することができ、光学素子を簡便且つ安価に製造することができる。

【００８７】なお、上記では石英のレンチキュラーレンズを用いる例について説明したが、屈折光学素子としては、上記アゾポリマーを溶解する溶剤に不溶であれば、どのような媒質のものでも良く、その形状も球面、非球面、凹レンズ等どのような形でも良い。

【００８８】〔第３の実施の形態〕本実施の形態の光学素子は、基体として屈折光学素子であるレンチキュラーレンズを用いると共に、レンチキュラーレンズの凹凸（第１凹凸）面にアゾポリマー層を形成し、更にこのアゾポリマー層の表面にレンズの凹凸より狭い間隔で屈折機能を有する凹凸（第２凹凸）を形成したものである。

【００８９】まず、第２の実施の形態と同様にして、石英のレンチキュラーレンズ１２Ａの凹凸面にアゾポリマーを均一にコートしてアゾポリマー層１４を形成する。アゾポリマー層１４はレンチキュラーレンズ１２Ａ表面の凹凸に沿って形成される。このレンチキュラーレンズは、図４（ａ）に示す構造を有しており、図４（ｂ）に示すように、入射光を半値全角が１０°となるように拡散させる。

【００９０】次に、図１３に示すスペックル転写光学系を用いて、アゾポリマー層１４の表面１４ａに拡散体からのスペックルパターンを転写する。即ち、光源４０からのレーザ光４２を１／４波長板４４により円偏光４６として拡散体４８に入射させ、拡散体４８の後方に出射される拡散光５０をアゾポリマー層１４の表面１４ａに照射する。これにより、図１４に示すように、アゾポリマー層１４にスペックルパターンに応じた凹凸５２が形成される。

【００９１】図１５にこの光学素子の水平方向及び垂直方向の拡散特性を示す。ここで水平方向とはレンチキュラーレンズのシリンドリカル面が並ぶ方向であり、垂直方向とはこれに直交する方向である。スペックルパターン転写後の拡散特性を実線で示し、スペックルパターン転写前の拡散特性を点線で示す。図１５から分かるように、アゾポリマー層１４にスペックルパターンに応じた凹凸５２を形成した光学素子の方が拡散角度が大きく拡散特性に優れている。

【００９２】以上の通り、本実施の形態の光学素子では、レンチキュラーレンズにより屈折効果が得られると共に、アゾポリマー層の表面に形成された微細な凹凸によっても屈折効果を得ることができ、素子の厚みを押さえつつ、より優れた屈折効果を得ることができる。また、任意の光パターンを照射して表面に所望形状の凹凸を誘起することにより、表面に凹凸を形成することができ、光学素子を簡便且つ安価に製造することができる。

【００９３】なお、上記では石英のレンチキュラーレンズを用いる例について説明したが、第２の実施の形態と同様に、他の屈折光学素子を用いてもよい。

【００９４】また、上記では拡散体から得られたスペックルパターンを転写する例について説明したが、計算機ホログラムまたはキノフォームに対応した強度分布の光を照射して、これらの強度分布に応じた凹凸を形成することもできる。計算機ホログラムとは、物体光と参照光とにより生じる干渉縞を計算し、計算結果に相当する強度分布の光で記録したホログラムである。計算機ホログラムについては、実施例において詳述する。キノフォームとは、強度や偏光方向ではなく、位相分布を記録したホログラムである。

【００９５】［大量生産に適した製造方法］次に、本発明の光学素子の複製物を大量生産する場合に好適な製造方法について説明する。本発明の光学素子は、上記の通り、アゾポリマー担体またはアゾポリマー層の表面に、屈折機能及び回折機能の少なくとも一方を有する所定形状の凹凸が形成されていることを特徴とするものである。従って、表面に形成された凹凸を転写することで、同じ凹凸形状を備えた光学素子を複製することができる。

【００９６】例えば、任意の光パターンを照射してアゾポリマー担体またはアゾポリマー層の表面に所望形状の凹凸を誘起した光学素子を用い、コンパクトディスクの製造工程と同様にして、光学素子に金蒸着や無電解メッキにより導電処理を施し、ニッケルなどの電鋳を行うことにより、この光学素子のネガの金型（メタルマスタ）を作製できる。この金型に基づいて、アクリル、ポリカーネイト、ポリエステルなどの樹脂材料に、熱圧着や射出成形加工などによってパターンを転写して、複製物（光学素子）を得ることができる。

【００９７】以下に、複製物の製造工程を説明する。まず、図１６（Ａ）に示すように、例えば、第１の実施の形態と同様にして、アゾポリマー担体１０の表面１０ａに凹凸２４が形成されると共に、凹凸２４の表面に微細な凹凸が形成された光学素子を作製する。次に、図１６（Ｂ）に示すように、この光学素子の凹凸２４及び微細な凹凸が形成された表面１０ａに、金を蒸着して薄膜メッキ層５４を形成する（マスタリング工程）。

【００９８】次に、図１６（Ｃ）で、薄膜メッキ層５４上にニッケル電鋳により所定厚さのメタルマスタ５６を形成し、図１６（Ｄ）で、形成されたメタルマスタ５６を薄膜メッキ層５４から剥離する。図１６（Ｅ）で、この剥離したメタルマスタ５６上にニッケル電鋳によりマ

ザー５８を形成し、図１７（A）で、マザー５８をメタルマスタ５６から剥離する。図１７（B）で、剥離したマザー５８上にニッケル電鋳によりスタンパ６０を形成し、図１７（C）で、スタンパ６０をマザー５８から剥離して、スタンパ６０が完成する（スタンパ作製工程）。このスタンパ６０は、アゾポリマー担体１０の表面１０ａに形成された凹凸２４及び微細な凹凸に対応する凹凸を備えている。

【００９９】次に、図１７（D）に示すように、このスタンパ６０を固定型６２及び移動型６４からなる射出成形機に取り付けて熱溶融したポリエステル樹脂６５を注入口（図示せず）から高圧力で注入して射出成形を行う。最後に、図１７（E）に示すように、射出成形機の温度が下がり、樹脂が硬化したところでポリエステル樹脂製の光学素子６６を取り出す。取り出された光学素子６６の表面６６ａには、アゾポリマー担体１０の表面１０ａに形成された凹凸２４及び微細な凹凸と同じ形状の凹凸が形成される（転写成形工程）。

【０１００】上記の方法では、光学素子からスタンパを作製し、このスタンパを用いて熱圧着または射出成形で複製物を製造するので、複製物を大量に生産するのに適している。

【０１０１】以上説明したように、本発明の光学素子は、アゾポリマーからなる高分子層の表面に形成された凹凸により、優れた屈折効果及び／または優れた回折効果を得ることができる。特に屈折効果に加えて回折効果を得る場合には、回折素子と屈折素子の両方の機能を兼ね備えるため、任意の形状のビームを得るのに有効であり、光バスシステム以外にも、結像光学素子、超解像レンズ、分光器、など多岐に渡る応用が期待できる。

【０１０２】また、室温近傍、好ましくは室温より高温のガラス転移点を有するアゾポリマーを用いる場合には、高分子層の表面に十分な深さの凹凸を容易且つ安定に形成することができ、設計の自由度が向上すると共に、優れた屈折効果及び／または優れた回折効果を得ることができる。

【０１０３】また、本発明の光学素子の製造方法によれば、光の干渉縞、スペックルパターン、計算機ホログラムなど任意の光パターンを照射することによって、複雑な凹凸を簡単に誘起することができ、簡便で安価に光学素子を作製することができる。更に、本発明の光学素子複製物の製造方法によれば、この光学素子をもとにスタンパを作製し、スタンパを用いて大量に複製物を製造することも可能である。また、得られた光学素子複製物によれば、本発明の光学素子と同様に、優れた屈折効果及び／または優れた回折効果を得ることができる。

【０１０４】なお、上記では、レンズ等の屈折光学素子に、屈折機能を有する凹凸や回折機能を有する凹凸を設ける例について説明したが、偏光板、波長板、反射板等の他の光学素子に、屈折機能を有する凹凸や回折機能を有する凹凸を設けることもできる。

【０１０５】

【実施例】次に、本発明を実施例により更に詳細に説明するが、本発明は以下の実施例に限定されるものではない。

（実施例１）本実施例では、図１８及び図１９を参照して、特開平１０－２８２３７１号公報に開示されているような光データバス及び信号処理装置に使用する光拡散分岐素子として好適な光学素子を作製した例について説明する。

【０１０６】アゾポリマーとしては、側鎖にシアノアゾベンゼンを持つポリエステル（例示化合物：アゾポリマー（２））を用いた。このアゾポリマー（２）のガラス転移温度Ｔｇは２６．８℃であり本発明に好適である。透明ガラス基板１２Ｂに、このアゾポリマー（２）を１．５μｍの厚さで塗布して、アゾポリマー層１４を備えた記録媒体を作製した。

【０１０７】図１８（ｂ）に示す光学系を用いて、空間光変調器１６により、水平方向に広がった光波（図１８（ａ）に示す光強度分布）を生成し、この光波をレンズ７０により集光しながら、物体光３０としてアゾポリマー層１４の表面１４ａに照射すると共に、ビームスプリッタ７２によって平行の参照光３２を同時に照射した。物体光３０及び参照光３２は互いに逆周りの円偏光に設定した。これにより効率よく表面レリーフホログラムが記録されて、アゾポリマー層１４の表面１４ａに微細な凹凸が形成される。凹凸のピッチは０．８～２．０μｍであった。

【０１０８】図１９に表面１４ａの状態を拡大して示す。図１９に示すように、十分な露光エネルギーで記録することにより、凹凸の深さが１μｍ以上の表面レリーフホログラムが誘起された。その結果、得られた光学素子に光を入射させると、殆ど０次回折光が現れず、図１８（ａ）に示す光強度分布の拡散光を得ることができた。従って、この光学素子は上述の光データバス用の光拡散分岐素子として好適である。

【０１０９】（実施例２）本実施例では、図２０～図２２を参照して、特開平１０－２８２３７１号公報に開示されているような光データバス及び信号処理装置に好適に使用される光拡散分岐素子とその作製方法とについて説明する。

【０１１０】アゾポリマーとしては、側鎖にシアノアゾベンゼンを持つポリエステル（例示化合物：アゾポリマー（３））を用いた。このアゾポリマー（３）のガラス転移温度Ｔｇは４８．５℃であり本発明に好適である。透明ガラス基板１２Ｂに、このアゾポリマー（３）を８．０μｍの厚さで塗布して、アゾポリマー層１４を備えた記録媒体を作製した。

【０１１１】図２０は、アゾポリマー層の表面に５～１００μｍの範囲でランダムなピッチのレンチキュラーレ

ンズを誘起するための光強度分布である。図５に示す光学系を用いて、図２０に示す光強度分布の光波を生成し、アゾポリマー層の表面に照射した。このときの光波は円偏光に設定した。これにより上記レンチキュラーレンズの作用を持つように、アゾポリマー層の表面に凹凸が形成される。

【０１１２】図２１にアゾポリマー層の表面状態を凹凸深さにより示す。十分な露光エネルギーで記録することにより、図２１に示すように、凹凸深さが最大１．２μｍの表面レリーフホログラムが誘起された。

【０１１３】図２２にこの光学素子の水平方向及び垂直方向の拡散特性を示す。図２２から分かるように、水平方向に０次透過光はなく、均一にビームが拡散している。一方、垂直方向にビームは広がらないことから、この光学素子は良好な非等方拡散を示した。即ち、本実施例では、表面に任意の凹凸形状を備えた屈折光学素子を容易に作製することができ、所望の拡散特性を得ることができる。

【０１１４】（実施例３）本実施例では、アゾポリマー層の表面に拡散体からスペックルパターンを転写して凹凸を形成し、光学素子を作製した例について説明する。

【０１１５】コヒーレント光を拡散体に透過させて拡散体の後方に生じるスペックルパターンを体積ホログラム記録した場合、そのホログラム自体が拡散特性を示すことが知られている。例えば、特開平４－２９９３０３号公報には、この効果を利用して屈折率がゆるやかに変化する拡散境界が記録されたホログラム拡散体が開示されている。これに対し、本実施例では、屈折率変化ではなく、スペックルパターンを直接アゾポリマー層の表面に凹凸として記録する方法について説明する。

【０１１６】アゾポリマーとしては、側鎖にシアノアゾベンゼンを持つポリエステル（例示化合物：アゾポリマー（５））を用いた。このアゾポリマー（５）のガラス転移温度Ｔｇは３７．８℃であり本発明に好適である。透明ガラス基板１２Ｂに、このアゾポリマー（５）を３．０μｍの厚さで塗布して、アゾポリマー層１４を備えた記録媒体を作製した。

【０１１７】次に、図２３に示すスペックル転写光学系を用いて、アゾポリマー層１４の表面１４ａに拡散体からのスペックルパターンを転写する。即ち、光源４０としてアルゴンイオンレーザの発振線４８８ｎｍを用い、光源４０からのレーザ光４２を１／４波長板４４により円偏光４６として拡散体４８に入射させた。拡散体４８としては楕円の拡散光を生成する非等方拡散体を用いた。拡散体４８の５ｍｍ後方に記録媒体を配置し、拡散体４８から出射される拡散光５０をアゾポリマー層１４の表面１４ａに照射した。アゾポリマー層１４に凹凸が十分に誘起されるように、光強度２．２Ｗ／ｃｍ^{2}のスペックルパターンを８時間照射した。これによりアゾポリマー層１４の表面１４ａにスペックルパターンに応じた凹凸が形成された光学素子（拡散体）が得られた。

【０１１８】図２４にアゾポリマー層１４の表面１４ａに誘起された凹凸パターンをＡＦＭ（原子間力顕微鏡）によって観察した結果を示す。凹凸深さの最大値は１μｍ程度であり、凹凸のピッチは略５μｍ～１００μｍの間を５０μｍを中心に分布した形状となった。このようにスペックルパターンが凹凸としてアゾポリマー層１４に転写された。

【０１１９】次に、この拡散体の拡散特性を評価した。図２５にこの光学素子の水平方向及び垂直方向の拡散特性を示す。図２５から分かるように、アゾポリマー層１４の拡散は、０次透過光は無く非等方拡散であった。この光学素子の拡散特性は、表面に形成された凹凸による屈折効果によって生じるものである。

【０１２０】このように本実施例では、屈折率分布ではなく表面の凹凸により屈折機能を有する光学素子（拡散体）を作製することができる。更に、この光学素子の凹凸を機械的に転写してスタンパを作製することができ、このスタンパを用いて同じ凹凸形状を備えた光学素子を大量生産することができる、というメリットを有する。

【０１２１】（実施例４）本実施例では、実施例２において作製された屈折型の光学素子に回折効果を付与するために、アゾポリマー層の表面に形成された凹凸の表面に更に微細な凹凸を形成し、光学素子を作製した例について説明する。

【０１２２】光源としてはアルゴンイオンレーザの発振線４８８ｎｍを用い、実施例２で作製された光学素子のアゾポリマー層の凹凸が形成された表面に、レーザ光を二光波に分岐して物体光及び参照光として照射する。物体光及び参照光の偏光は１／４波長板によって互いに逆周りの円偏光とした。この偏光配置により効率よく表面レリーフホログラムを作製することができ、アゾポリマー層に形成された凹凸の表面に、凹凸のピッチが１μｍ以下、凹凸深さが２００ｎｍ以下の微細な凹凸を形成することができた。

【０１２３】記録光（物体光及び参照光）の露光エネルギーを調節することで、プラス１次光、マイナス１次光、及び０次光を均等に回折するようした。これにより、図９（ａ）に示すように３分岐の拡散光が生成される。この場合の拡散光のビームプロファイルは図９（ｂ）に示す通りである。

【０１２４】このように本実施例では、屈折機能を備える凹凸の表面に微細な凹凸を付加することにより、回折効果を付加することができる。また、本実施例の光学素子では、レンチキュラーレンズによる屈折効果とアゾポリマー層の表面に形成された微細な凹凸による回折効果の両方が得られるので、用途に応じて複雑なビームプロファイルを得ることができる。

【０１２５】なお、実施例３において作製された屈折型の光学素子についても、同様の方法で回折効果を付与す

ることができる。

【０１２６】（実施例５）本実施例では、図２６〜図２８を参照して、特開平１０－２８２３７１号公報に開示されているような光データバス及び信号処理装置に使用する光拡散分岐素子として好適な光学素子を作製した例について説明する。

【０１２７】アゾポリマーとしては、側鎖にシアノアゾベンゼンを持つポリエステル（例示化合物：アゾポリマー（６））を用いた。このアゾポリマー（６）のガラス転移温度Ｔｇは３３．１℃であり本発明に好適である。

【０１２８】まず、アゾポリマー（６）のクロロホルム溶液をスピンコートによりレンチキュラーレンズ１２Ａの凹凸面に塗布した。このとき、アゾポリマー層１４の厚みは１μｍとした。アゾポリマー層１４はレンチキュラーレンズ１２Ａ表面の凹凸に沿って形成された。レンチキュラーレンズとしては、図４（ａ）に示す石英のレンチキュラーレンズを用いた。このレンズは、図４（ｂ）に示すように、入射光を半値全角が１０°拡散させる。また、レンチキュラーレンズの凹凸のピッチは１６６μｍであり、凹凸の深さは５０μｍである。

【０１２９】次に、図４（ａ）に示す石英のレンチキュラーレンズの拡散角をトップハット状のビームに形成するために、図２７に示す光学系を用いて、表面レリーフホログラムを作製する。まず、空間光変調器１６により、図２６（ａ）に示す光強度分布の光波を生成した。この光波は、レンチキュラーレンズ１２Ａによる拡散光をトップハット状の光強度分布に変形するようにあらかじめ設計されている。

【０１３０】生成した光波をレンズ７０により集光しながら物体光３０として照射すると共に、ビームスプリッタ７２によって平行の参照光３２を同時に照射した。物体光３０及び参照光３２は、略同軸でアゾポリマー層１４の表面１４ａとは反対側の表面１４ｂから入射した。物体光３０及び参照光３２は互いに逆周りの円偏光に設定した。また、レリーフホログラムの回折効率が略５０％となるように露光エネルギーを調整した。これにより表面レリーフホログラムが記録されて、アゾポリマー層１４の表面１４ａに微細な凹凸が形成される。凹凸のピッチは０．５〜２．０μｍであり、凹凸の深さは２００ｎｍ以下であった。

【０１３１】次に、アゾポリマー層１４の表面１４ａ側から光を入射させ、ホログラムを再生した。即ち、入射した光のうち半分の光は表面レリーフホログラムにより回折され、その後レンチキュラーレンズにより屈折されて拡散した。また、ホログラムにより回折されない残りの半分の光は、そのままレンチキュラーレンズによって拡散された。図２８に示すように、結果として、この二つの拡散光が合わさることによりトップハット状の拡散光を得ることができた。

【０１３２】このように本実施例では、半分の光を屈折光学素子によって拡散させ、かつ、残り半分の光はその拡散光を補うように回折光学素子で生成される。従って、上述の光データバス用の光拡散分岐素子として好適である。

【０１３３】（実施例６）本実施例では、アゾポリマー層の表面に計算機ホログラムを転写して凹凸を形成し、光学素子を作製した例について説明する。

【０１３４】まず、計算機ホログラムについて説明する。原理的には、計算機ホログラムの入力面での光の複素振幅、即ち位相と実振幅の両方を決めると、計算機ホログラムの出力面での複素振幅を決めることができる。この２つの複素振幅の関係は、解析的な変換関係で記述でき、両者があまり接近していない場合にはフーリエ変換の関係にある。しかし、位相と振幅をともに変調する素子の実現は難しく、振幅のみ、位相のみを変調するのが普通である。位相あるいは振幅のみの変調では、所望の出力と計算機ホログラムとの間には一意的な関係が無く、探索的な最適化手法に頼らざるを得ない。

【０１３５】最適化の手法としては、収束するまで繰り返しフーリエ変換を行うGerchberg-Saxton法、シュミレーッテッド・アニーリング法などのニューラルネットの手法を用いる方法、遺伝的アルゴリズムを用いる方法などがある。ここではシンプルなパターンでは比較的収束が速いGerchberg-Saxton法を用い、計算機ホログラムを算出した。

【０１３６】図２９（ｂ）は、出力面での光強度分布であり、図２９（ａ）は、それを形成するための入力面での計算機ホログラムである。計算機ホログラムは入力面での位相分布を表しており、白い部分が位相差πに対応し、黒い部分が位相差－πに対応している。この例では、位相差パターンを図２９（ｂ）に示すような濃淡画像としてアゾポリマーに照射し、明るい部分で表面を誘起させる。この誘起されたレリーフ構造によって入射光の位相を変調する。従って、計算機ホログラムに対応する位相差に等しい凹凸を誘起する必要がある。

【０１３７】この計算機ホログラムを、図５に示した光学系によってアゾポリマー担体１０の表面１０ａに縮小して結像した。アゾポリマーとしては、側鎖にシアノアゾベンゼンを持つポリエステル（例示化合物：アゾポリマー（７））を用いた。このアゾポリマー（７）のガラス転移温度Ｔｇは３８℃であり本発明に好適である。凹凸の深さの最大値は１μｍ程度であり、凹凸の最小ピッチは１μｍ程度であった。

【０１３８】このように計算機ホログラムが凹凸としてアゾポリマー担体に転写された。アゾポリマー担体の表面をＡＦＭによって観察した結果を図３２に示す。また、得られた光学素子に光を入射させ、その出射光を評価した結果を図３０に示す。図３０より、計算機ホログラムは４分岐に設計したにもかかわらず、出射光は０次回折光のある５分岐の光波となった。これは、位相差π

に相当する凹凸がアゾポリマー担体の表面に誘起されなかったため１００％の回折効率が得られなかったことに起因する。

【０１３９】次に、得られた光学素子にレンズ特性を持たせるために、図６に示したレンチキュラーレンズの形状に対応した明暗画像を、計算機ホログラムが凹凸として転写されたアゾポリマー担体の表面に照射した。このとき、図５に示した光学系を使用した。これによってレンチキュラーレンズの作用を持つようにアゾポリマーに凹凸を誘起した。凹凸のピッチは１０μｍであった。得られた光学素子に光を入射させると、図３１に示すモードプロファイルの５分岐の拡散光を得ることができた。

【０１４０】（実施例７）本実施例では、実施例３、実施例６で作製した光学素子を用いて、光学素子を複製するためのメタルマスタを作製した例について説明する。

【０１４１】光学素子の凹凸が形成された表面（正確にはアゾポリマー層またはアゾポリマー担体の表面）に、蒸着あるいは無電解メッキによって導電性処理を施す。次に、ニッケル電鋳などにより光学素子のネガの金型であるメタルマスタを作製することができる。凹凸が精密に転写されたメタルマスタを得ることができれば、後はこのメタルマスタを用いてスタンパを作製し、このスタンパを用いて、アクリル、ポリカーネイト、ポリエステルなどの樹脂材料に、熱圧着や射出成形加工などによって凹凸パターンを転写することにより、容易に複製物を得ることができる。

【０１４２】図３３（ａ）及び（ｂ）は、実施例３で得られた光学素子を用いて作製したメタルマスタ表面のＡＦＭ像である。凹凸が誘起されたアゾポリマー層の表面に無電解メッキを施し、その後ニッケル電鋳により金型であるメタルマスタを作製した。図３３（ａ）及び（ｂ）と図２４とを比較することにより、アゾポリマー層の表面形状が正確にメタルマスタに転写されていることがわかる。

【０１４３】図３４（ａ）及び（ｃ）は、実施例６で得られた光学素子のアゾポリマー層表面のＡＦＭ像であり、図３４（ｂ）及び（ｄ）は、これを用いて作製したメタルマスタ表面のＡＦＭ像である。凹凸が誘起されたアゾポリマー層の表面に金蒸着を施し、その後ニッケル電鋳によりメタルマスタを作製した。図３４（ａ）～（ｄ）より、アゾポリマー層の表面形状が正確にメタルマスタに転写されていることがわかる。

【０１４４】従って、このメタルマスタを用いて上記の方法で光学素子を製造することにより、複雑な凹凸を備えた光学素子であっても、その複製を簡便かつ低コストに大量生産することができる。

【０１４５】（実施例８）本実施例では、レンチキュラーレンズの表面に形成されたアゾポリマー層の表面に拡散体からのスペックルパターンを転写して凹凸を形成し光学素子を作製した例について説明する。

【０１４６】アゾポリマーとしては、側鎖にシアノアゾベンゼンを持つポリエステル（例示化合物：アゾポリマー（４））を用いた。このアゾポリマー（４）のガラス転移温度Ｔｇは４８．５℃であり本発明に好適である。

【０１４７】まず、アゾポリマー（４）のクロロホルム溶液をスピンコートによりレンチキュラーレンズ１２Ａの凹凸面に塗布し、厚さ３μｍのアゾポリマー層１４を形成した。アゾポリマー層１４はレンチキュラーレンズ１２Ａ表面の凹凸に沿って形成された。レンチキュラーレンズとしては、図４（ａ）に示す石英のレンチキュラーレンズを用いた。このレンズは、図４（ｂ）に示すように、入射光を半値全角が１０°拡散させる。また、レンチキュラーレンズの凹凸のピッチは１６６μｍである。

【０１４８】次に、図１３に示すスペックル転写光学系を用いて、アゾポリマー層１４の表面１４ａに拡散体からのスペックルパターンを転写する。即ち、光源としてアルゴンイオンレーザの発振線４８８ｎｍを用い、光源４０からのレーザ光４２を１／４波長板４４により円偏光４６として拡散体４８に入射させた。拡散体４８としては楕円の拡散光を生成する非等方拡散体を用いた。拡散体４８の５ｍｍ後方にアゾポリマー層１４を備えた記録媒体を配置し、拡散体４８の後方に出射される拡散光５０をアゾポリマー層１４の表面１４ａに照射した。アゾポリマー層１４の表面１４ａに凹凸が十分に誘起されるように、光強度２．２Ｗ／ｃm^2のスペックルパターンを８時間照射した。これにより、図１４に示すように、アゾポリマー層１４にスペックルパターンに応じた凹凸５２が形成された光学素子（拡散体）が得られた。なお、凹凸５２の凹凸深さの最大値は１μｍ程度であり、凹凸ピッチは略５μｍ～１００μｍの範囲に５０μｍを中心に分布した形状となった。

【０１４９】図１５にこの光学素子の水平方向及び垂直方向の拡散特性を示す。スペックルパターン転写後の拡散特性を実線で示し、スペックルパターン転写前の拡散特性を点線で示す。図１５から分かるように、アゾポリマー層１４にスペックルパターンに応じた凹凸５２を形成した光学素子の方が拡散特性に優れている。即ち、アゾポリマー層１４の表面に形成された凹凸５２による２次的な屈折効果により拡散特性が向上した。

【０１５０】また、本実施例では、屈折率分布ではなく表面の凹凸による拡散素子を作製することができる。従って、この光学素子表面の凹凸を機械的に転写してネガのマスター拡散体を作製し、このマスター拡散体に基づいて複製物を大量生産することができる、というメリットがある。

【０１５１】

【発明の効果】本発明の光学素子は、表面に形成された凹凸により、優れた屈折効果または回折効果を得ることができる、という効果を奏する。

【０１５２】また、屈折機能を有する凹凸及び回折機能を有する凹凸を兼ね備えるように構成した場合には、屈折効果及び回折効果により、任意の形状の光ビームを得ることができる、という効果を奏する。

【０１５３】また、所定範囲のガラス点移転を有する高分子材料を用いた場合には、表面に十分な深さの凹凸（レリーフ構造）を形成することにより、設計の自由度が向上すると共に、優れた屈折効果及び／または優れた回折効果を得ることができる、という効果を奏する。

【０１５４】本発明の光学素子の製造方法は、任意の光パターンを照射して表面に所望形状の凹凸を誘起することにより、表面に凹凸が形成された光学素子を簡便且つ安価に製造することができる、という効果を奏する。

【０１５５】本発明の光学素子複製物の製造方法は、表面に凹凸が形成された光学素子を用いてスタンパを作製するので、同じ表面形状の光学素子を容易に複製でき、大量生産が可能になる、という効果を奏する。また、得られた光学素子複製物は、本発明の光学素子と同様に、優れた屈折効果及び／または優れた回折効果を得ることができる、という効果を奏する。

【図面の簡単な説明】

【図１】例示化合物のＤＳＣ曲線を示す線図である。

【図２】レリーフ深さと露光エネルギーとの関係を示す線図である。

【図３】（ａ）及び（ｂ）は本発明の光学素子の積層構成を示す概略断面図である。

【図４】（ａ）はレンチキュラーレンズの構造を示す概略断面図であり、（ｂ）は（ａ）に示すレンズの拡散特性を示す線図である。

【図５】第１の実施の形態に係る光学素子の製造工程における露光光学系を示す光軸に沿った概略断面図である。

【図６】レンチキュラーレンズの形状に対応した光強度分布を示す図である。

【図７】（ａ）は第１の実施の形態に係る光学素子の製造工程において粗い凹凸が形成された段階を示す概略断面図であり、（ｂ）は（ａ）に示す光学素子の拡散光のビームプロファイルを示す線図である。

【図８】第１の実施の形態に係る光学素子の製造工程において微細な凹凸が形成された段階を示す概略断面図である。

【図９】（ａ）は第１の実施の形態に係る光学素子から射出される拡散光を示す概略断面図であり、（ｂ）は（ａ）に示す拡散光のビームプロファイルを示す線図である。

【図１０】第２の実施の形態に係る光学素子の製造工程においてレンズの凹凸面に高分子層が形成された段階を示す概略断面図である。

【図１１】第２の実施の形態に係る光学素子の製造工程において高分子層に微細な凹凸が形成された段階を示す概略断面図である。

【図１２】（ａ）は第２の実施の形態に係る光学素子から射出される拡散光を示す概略断面図であり、（ｂ）は（ａ）に示す拡散光のビームプロファイルを示す線図である。

【図１３】第３の実施の形態に係る光学素子の製造工程における露光光学系を示す光軸に沿った概略断面図である。

【図１４】第３の実施の形態に係る光学素子の製造工程において高分子層に微細な凹凸が形成された段階を示す概略断面図である。

【図１５】第３の実施の形態に係る光学素子の拡散特性を示す線図である。

【図１６】（Ａ）～（Ｅ）は光学素子の製造工程を示す部分断面図である。

【図１７】（Ａ）～（Ｅ）は光学素子の製造工程を示す部分断面図である。

【図１８】（ａ）は実施例１で用いる光強度分布を示す図であり、（ｂ）は実施例１の光学素子の製造工程における露光光学系を示す光軸に沿った概略断面図である。

【図１９】実施例１の光学素子の表面状態を示す拡大図である。

【図２０】実施例２で用いるランダムなピッチのレンチキュラーレンズの形状に対応した光強度分布を示す図である。

【図２１】実施例２の光学素子の表面状態を示す線図である。

【図２２】実施例２の光学素子の拡散特性を示す線図である。

【図２３】実施例３の光学素子の製造工程におけるスペックル転写光学系を示す光軸に沿った概略断面図である。

【図２４】実施例３の光学素子の表面状態をＡＦＭで観察した様子を示す斜視図である。

【図２５】実施例３の光学素子の拡散特性を示す線図である。

【図２６】（ａ）は実施例５で用いる光強度分布を示す図であり、（ｂ）は実施例５の光学素子の拡散特性を示す線図である。

【図２７】実施例５の光学素子の製造工程における露光光学系を示す光軸に沿った概略断面図である。

【図２８】実施例５の光学素子から射出される拡散光のビームプロファイルを示す線図である。

【図２９】（ａ）は実施例６の光学素子の入力面での計算機ホログラムであり、（ｂ）は出力面での光強度分布である。

【図３０】実施例６の光学素子から射出される拡散光のビームプロファイルを示す線図である。

【図３１】実施例６の光学素子（レンズ特性付与）から射出される拡散光のビームプロファイルを示す線図であ

る。

【図３２】実施例６の光学素子の表面状態をＡＦＭで観察した様子を示す図である。

【図３３】（ａ）は実施例３の光学素子を用いて作製したメタルマスタの表面状態をＡＦＭで観察した様子を示す斜視図であり、（ｂ）は（ａ）のスケールに沿った部分断面図である。

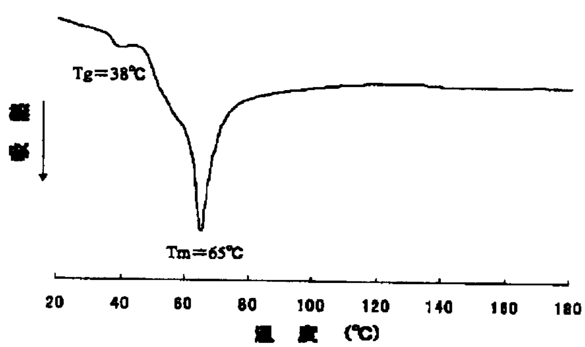
【図３４】（ａ）は実施例６の光学素子の表面状態をＡＦＭで観察した様子を示す斜視図、（ｂ）は実施例６の光学素子を用いて作製したメタルマスタの表面状態をＡＦＭで観察した様子を示す斜視図、（ｃ）は（ａ）のスケールに沿った部分断面図、（ｄ）は（ｂ）のスケールに沿った部分断面図である。

【図３５】（ａ）及び（ｂ）は、光データバスの従来技術を示す図であり、（ｃ）は光データバスの屈折光学素子に代えて回折光学素子を取り付けた場合の図である。

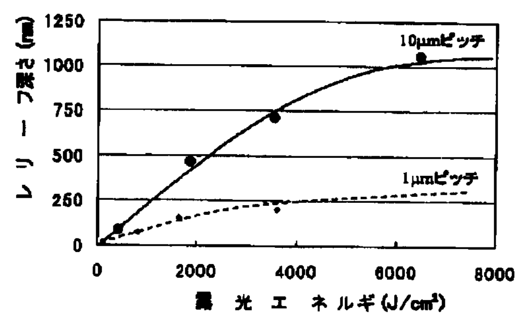
【符号の説明】

１０　アゾポリマー担体
１０ａ　表面
１２　基体
１２Ａ　レンチキュラーレンズ
１４　アゾポリマー層　＊
＊１４ａ　表面
１６　空間光変調器
１８　光波
２０，２２　レンズ
２４　凹凸
２６　光（入射光）
２８　拡散光
３０　物体光
３２　参照光
３４　プラス１次光
３６　マイナス１次光
３８　０次光
４０　光源
４４　１／４波長板
４６　円偏光
４８　拡散体
５０　拡散光
５２　凹凸
５６　メタルマスタ
５８　マザー
６０　スタンパ

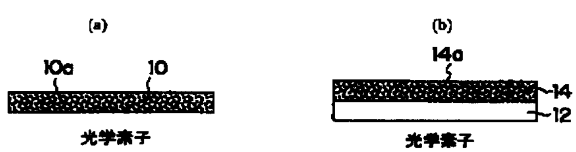
【図１】



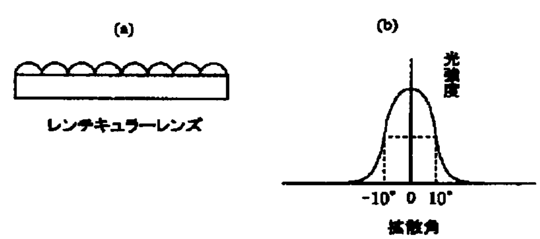
【図２】



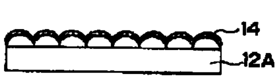
【図３】



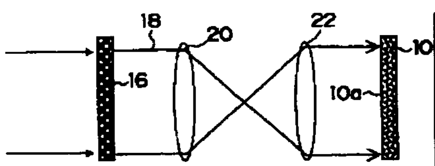
【図４】



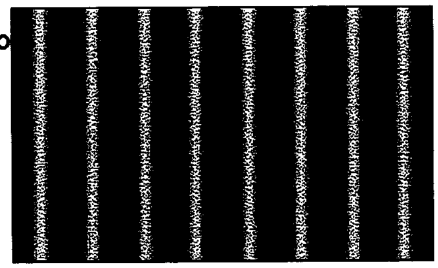
【図１０】



【図５】

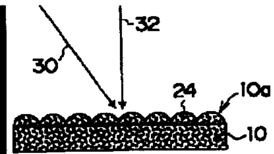


【図６】

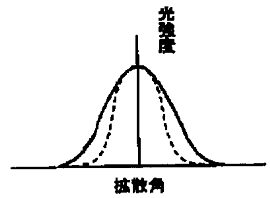


光強度分布の一例

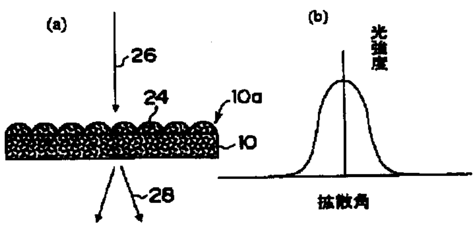
【図８】



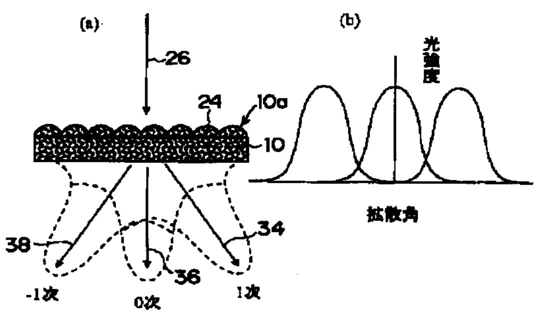
【図１５】



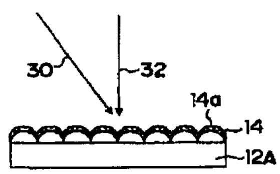
【図７】



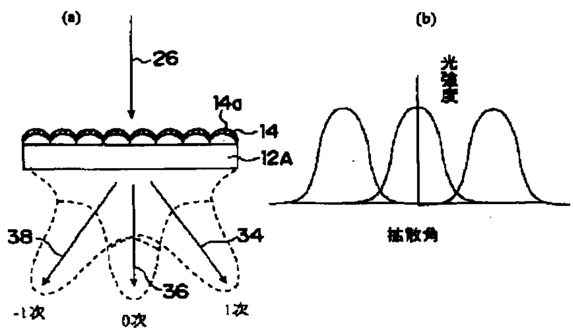
【図９】



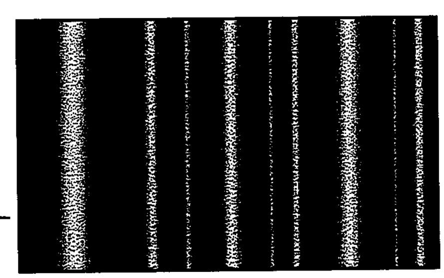
【図１１】



【図１２】

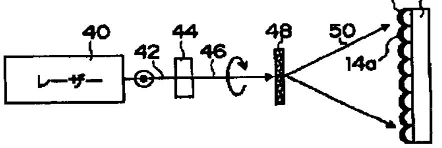


【図２０】

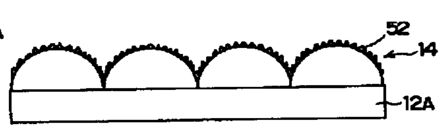


光強度分布の一例

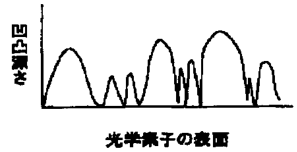
【図１３】



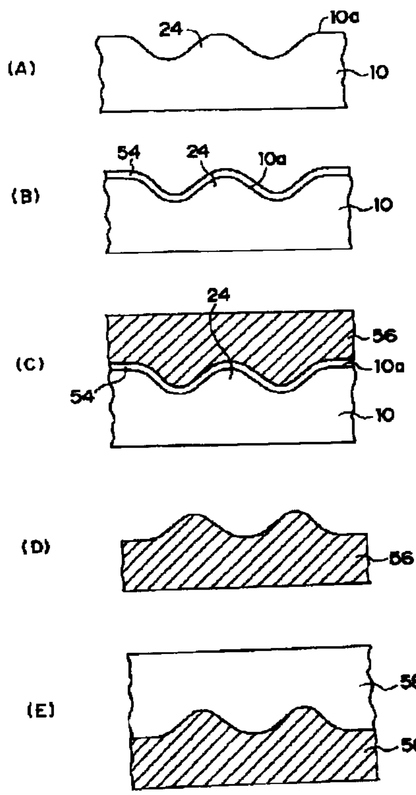
【図１４】



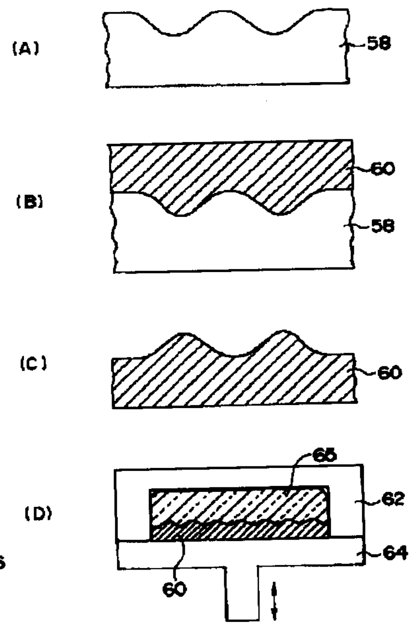
【図２１】



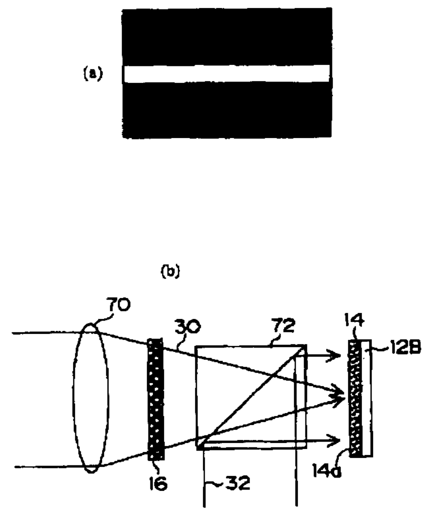
【図１６】



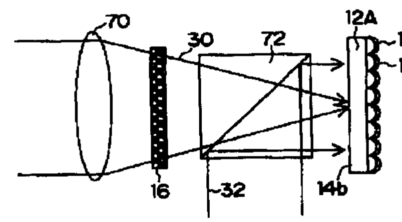
【図１７】



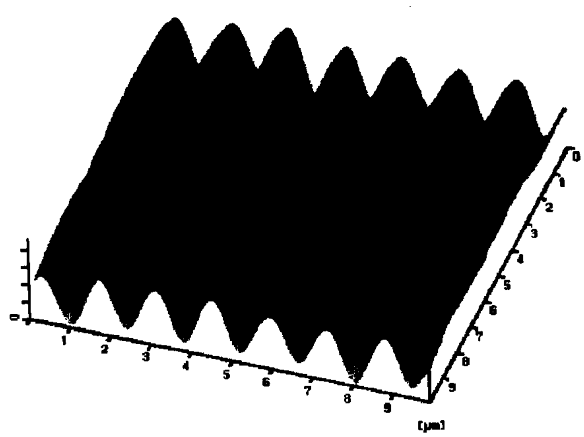
【図１８】



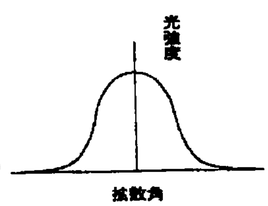
【図２７】



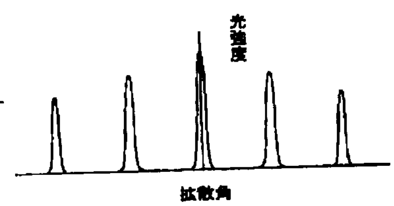
【図１９】



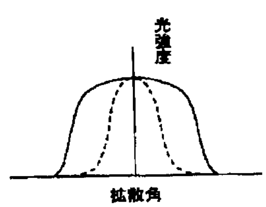
【図２２】



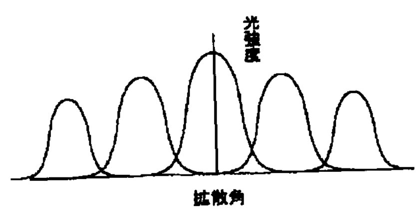
【図３０】



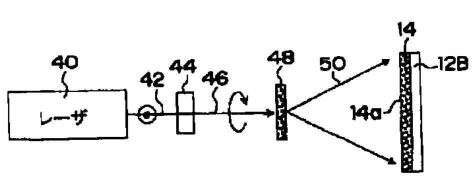
【図２８】



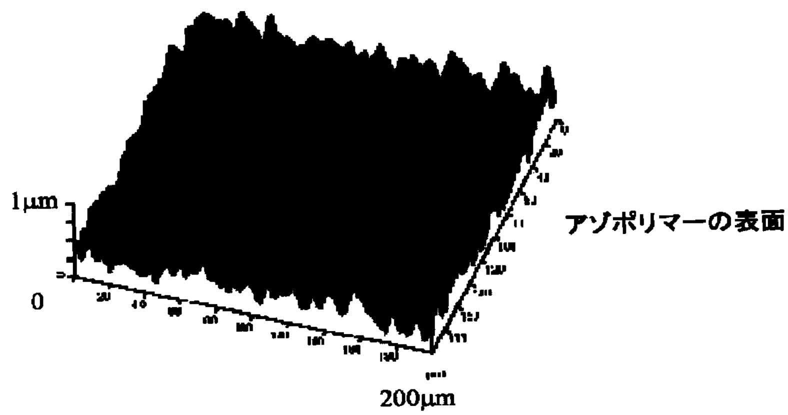
【図３１】



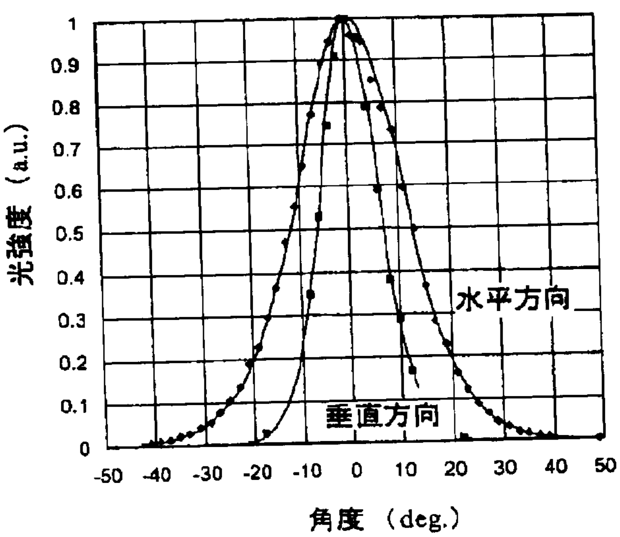
【図２３】



【図２４】

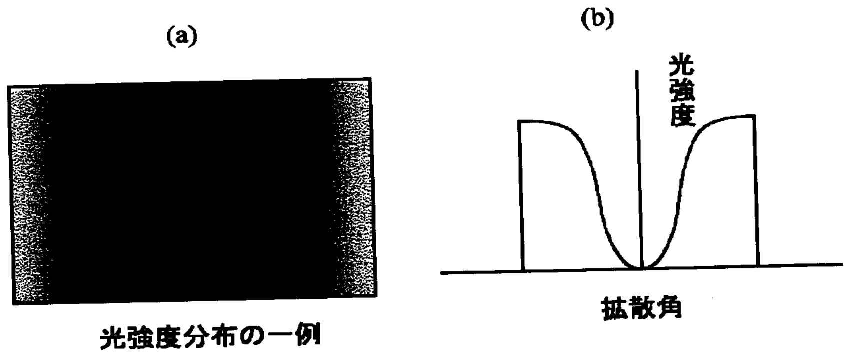


【図２５】

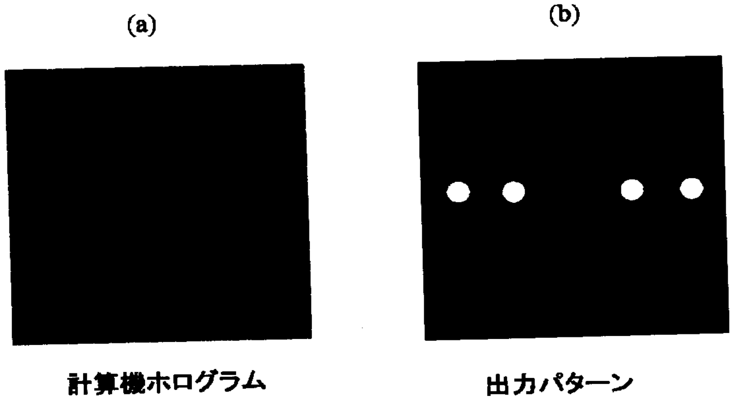


【図３２】

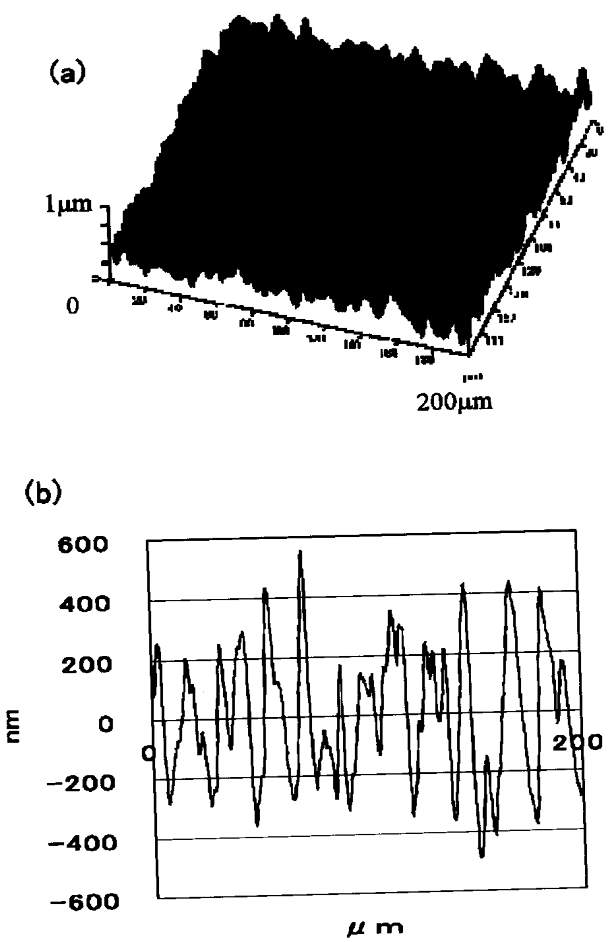
【図２６】



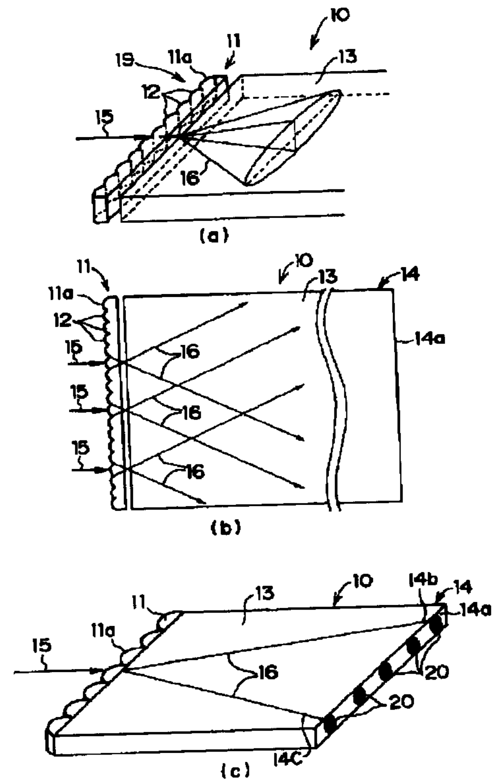
【図２９】


(a)
(b)
計算機ホログラム
出力パターン

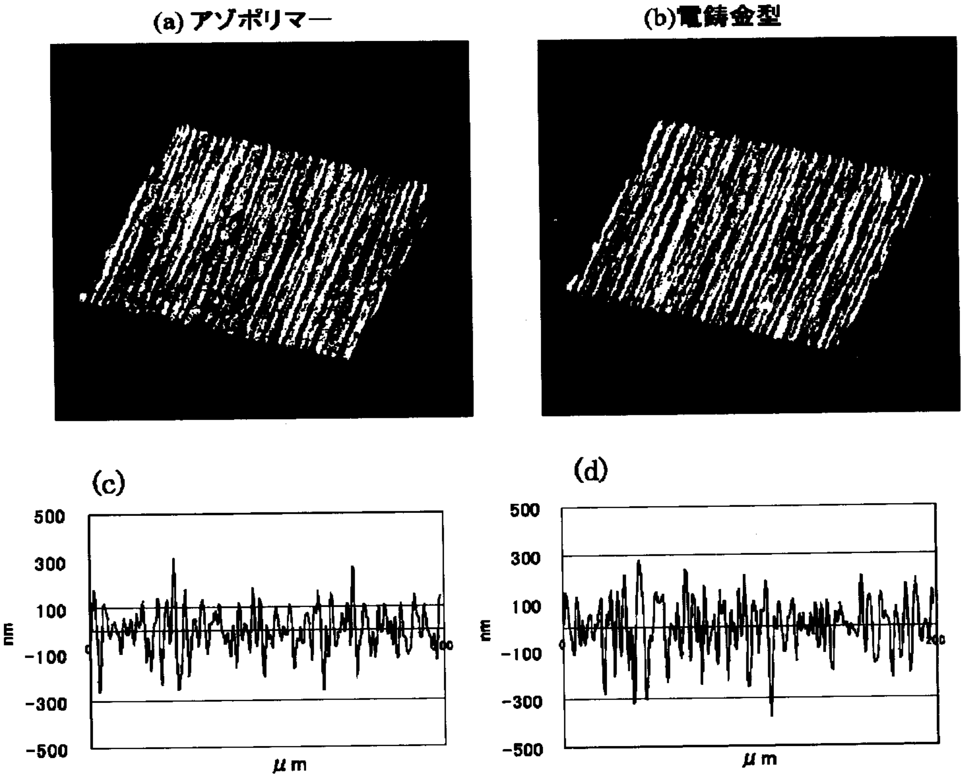
【図３３】


(a)
1μm
0
200μm
(b)
600
400
200
0
-200
-400
-600
nm
0
200
μm

【図３５】


10
11
11a
19
12
13
15
16
(a)
14
14a
(b)
14b
20
14C
(c)

【図３４】



フロントページの続き

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TECHNICAL FIELD

[Field of the Invention] Especially this invention is equipped with the macromolecule layer which has an azobenzene frame about the manufacture approach of the manufacture approach of an optical element and an optical element, an optical element duplicate object, and an optical element duplicate object, and relates to the manufacture approach of the optical element which has either [at least] a refraction function or a diffraction function, the manufacture approach of the optical element, the duplicate object of the optical element, and an optical element duplicate object.

[Translation done.]

PRIOR ART

[Description of the Prior Art] Conventionally, in the field of an optical instrument, the optical element (dioptrics component) using optical refraction, such as a convex lens, a concave lens, and prism, has been used widely. Recently, production of a micro-lens array, a lenticular lens, etc. is also attained by development of ultra-fine processing technology, and the dioptrics component is used in various applications from lighting to optical communication.
[0003] For example, the signal processor using the optical data bus equipped with the lenticular lens and this optical data bus is indicated by JP,10-282371,A. This optical data bus 10 forms two or more cylindrical sides (lenticular lens) 12 arranged along with edge 11a which makes the optical data bus 10 interior diffuse the signal light 15 which carried out incidence to one edge 11a of the signal light incidence section 11, as shown in drawing 35 (a) and (b). Since the cylindrical side 12 diffuses the signal light 15 by which incidence was carried out to the optical data bus 10 over the whole surface of edge 14a by the side of the signal light outgoing radiation section 14 with the diffusion means which comes to carry out two or more arrays, the signal light left besides the optical transmission layer 13 among signal light is stopped to the minimum. The transmission efficiency of the signal light 15 becomes high by this, and dispersion in the amount of outgoing radiation in edge 14a by the side of the signal light outgoing radiation section 14 decreases. For this reason, low consumption electrical quantity-ization can be attained in the signal processor using the optical data bus 10.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] The optical element of this invention does so the effectiveness that the outstanding refraction effectiveness or the outstanding diffraction effect can be acquired with the irregularity formed in the front face.
[0152] Moreover, when it constitutes so that it may have the irregularity which has the irregularity and the diffraction function to have a refraction function, the effectiveness that the light beam of the configuration of arbitration can be obtained is done so according to the refraction effectiveness and the diffraction effect.
[0153] Moreover, when the polymeric materials which have glass point relocation of the predetermined range are used, while the degree of freedom of a design improves by forming the irregularity (relief structure) of sufficient depth for a front face, the effectiveness that the outstanding refraction effectiveness and/or the outstanding diffraction effect can be acquired is done so.
[0154] The manufacture approach of the optical element of this invention does so the effectiveness that the optical element by which irregularity was formed in the front face can be manufactured simple and cheaply, by irradiating the optical pattern of arbitration and carrying out induction of the irregularity of a request configuration to a front face.
[0155] Since the manufacture approach of the optical element duplicate object of this invention produces La Stampa using the optical element by which irregularity was formed in the front face, it can reproduce easily the optical element of the shape of same surface type, and does so the effectiveness that mass production method becomes possible. Moreover, the obtained optical element duplicate object does so the effectiveness that the outstanding refraction effectiveness and/or the outstanding diffraction effect can be acquired like the optical element of this invention.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, dioptrics components, such as a lens, are equipped only with the function of comparatively simple condensing or optical diffusion. For example, in an above-mentioned optical data bus, signal light is only diffused with the lenticular lens. On the other hand, when Holographic Optical Element (HOE) which is a diffracted-light study component using the diffracted-light study component which used the diffraction of light instead of and a hologram is used, a complicated light wave can be generated. [the dioptrics component]
[0005] For example, in the above-mentioned optical data bus 10, as shown in drawing 35 (c) The signal light 15 by which incidence was carried out to it in the optical data bus 10 when the diffusion plate 20 had been arranged to one edge 11a of the signal light incidence section 11 as a diffracted-light study component instead of the lenticular lens It diffracts with the diffusion plate 20, and it is spread, while branching so that it may condense to the predetermined output port (for example, output ports 14b and 14c) established in edge 14a by the side of the signal light outgoing radiation section 14.
[0006] According to the diffracted-light study component this passage, an incident wave side is convertible for the wave front designed to arbitration. Moreover, the diffracted-light study component had the variance contrary to a refraction mold lens, and since it does not have thickness substantially, it is equipped with the advantage which is not in a dioptrics component -- optical system becomes compact. On the other hand, in order [the] to use the diffraction of light, there is a trouble of diffraction efficiency essentially falling compared with a dioptrics component according to generating of zero-order light with large wavelength dispersion with large constraint of alignment.
[0007] moreover, as the production approach of a diffracted-light study component of having used the hologram Photofabrication of surfaces for holograms, As indicated by Sukant Tripathy, Dong-Yu Kim, Lian Li, and Jayant Kumar, and CHEMTECH MAY (1998) pp.34-40. The approach of forming in a medium front face the surface relief hologram with which induction of the detailed irregularity was carried out by recording a hologram on this record medium is learned using the record medium which consists of a macromolecule (azo polymer) which has an azobenzene frame.
[0008] Using the laser light source of the wavelength which has sensibility in an azo polymer, two light waves are made to interfere and, specifically, the surface relief hologram of a submicron pitch is formed on the surface of a record medium. Although the HOE production process in which the usual semi-conductor process is used needs many processes in order to repeat a pattern design, exposure, and development two or more times, by the above-mentioned approach, it can skip many processes and can reduce a manufacturing cost sharply. Moreover, since the relief depth of the surface relief hologram formed increases in proportion to exposure energy, production of an ideal diffracted-light study component from which irregularity changed gently is possible for it.
[0009] However, the relief depth obtained by the above-mentioned approach is about several 100nm, when forming a surface relief hologram and using it as a diffracted-light study component, sufficient relief depth is not obtained, but the zero-order light which is not diffracted occurs and the practical problem that diffraction efficiency falls usually generates it.
[0010] Although there is an advantage that the degree of freedom of a design is large in the diffracted-

light study component containing HOE as stated above, there are problems, like in order to use the diffraction of light, constraint of alignment is essentially large, and wavelength dispersion is large. On the other hand, although the degree of freedom of a design is small, dioptrics components, such as a lens, have little constraint of alignment, wavelength dispersion is small for them, and the problem by zero-order light has the advantage (robustness of a dioptrics component) of not generating in them.
[0011] This invention is made in view of the above-mentioned trouble, and the 1st purpose of this invention is to offer the optical element which can acquire the outstanding refraction effectiveness or the outstanding diffraction effect with the irregularity formed in the front face. The 2nd purpose of this invention is to offer the optical element which can obtain the light beam of the configuration of arbitration according to the refraction effectiveness and the diffraction effect. It is to offer the optical element which can acquire the outstanding refraction effectiveness and/or the outstanding diffraction effect while the degree of freedom of the purpose [3rd] of this invention of a design improves by forming the irregularity (relief structure) of sufficient depth for a front face.
[0012] The 4th purpose of this invention is by irradiating the optical pattern of arbitration and carrying out induction of the irregularity of a request configuration to a front face to offer the manufacture approach of an optical element that the optical element by which irregularity was formed in the front face can be manufactured simple and cheaply. Using the optical element by which irregularity was formed in the front face, the 5th purpose of this invention can reproduce easily the optical element of the shape of same surface type, and is to offer the optical element duplicate object obtained by the manufacture approach and approach of the suitable optical element duplicate object for mass production method.

[Translation done.]

MEANS

[Means for Solving the Problem] In order to attain the 1st above-mentioned purpose, an optical element according to claim 1 is equipped with the macromolecule layer which has an azobenzene frame, and is characterized by forming in the front face of this macromolecule layer the irregularity which has a refraction function. In this optical element, the refraction effectiveness can be acquired with the irregularity formed in the front face of a macromolecule layer. Moreover, although diffraction efficiency falls if sufficient concavo-convex depth is not obtained, in this optical element, the outstanding refraction effectiveness can be acquired by optimizing concavo-convex spacing irrespective of the concavo-convex depth.
[0014] In order to attain the 1st above-mentioned purpose, an optical element according to claim 2 is equipped with the macromolecule layer which has an azobenzene frame, and is characterized by forming in the front face of this macromolecule layer irregularity with a depth of 1 micrometers or more which has a diffraction function. The outstanding diffraction effect can be acquired in this optical element, without diffraction efficiency falling with irregularity with a depth of 1 micrometers or more formed in the front face of a macromolecule layer.
[0015] In order to attain the 1st or 2nd above-mentioned purpose, an optical element according to claim 3 is equipped with the macromolecule layer which has an azobenzene frame, and it is characterized by forming in the front face of this 1st irregularity the 2nd irregularity which has a refraction function or a diffraction function while the 1st irregularity which has a refraction function is formed in the front face of this macromolecule layer. In this optical element, while the refraction effectiveness is acquired with the 1st irregularity formed in the front face of a macromolecule layer, the refraction effectiveness or the diffraction effect can be acquired with the 2nd irregularity formed in the front face of the 1st irregularity.

[0016] That is, in addition to the refraction effectiveness by the 1st irregularity, the outstanding refraction effectiveness can be acquired by acquiring the refraction effectiveness by the 2nd irregularity. Moreover, when acquiring the diffraction effect by the 2nd irregularity in addition to the refraction effectiveness by the 1st irregularity, the light beam of the configuration of arbitration can be obtained.
[0017] In order to attain the 1st or 2nd above-mentioned purpose, an optical element according to claim 4 is equipped with a dioptrics component and the macromolecule layer which has the azobenzene frame formed in the front face of this dioptrics component, and is characterized by forming in the front face of this macromolecule layer the irregularity which has either [at least] a refraction function or a diffraction function. In this optical element, while the refraction effectiveness is acquired by the dioptrics component, either [at least] the refraction effectiveness or the diffraction effect can be acquired with the irregularity formed in the front face of a macromolecule layer.
[0018] That is, in addition to the refraction effectiveness by the dioptrics component, the outstanding refraction effectiveness can be acquired by acquiring the refraction effectiveness by irregularity. Moreover, when acquiring the diffraction effect by irregularity in addition to the refraction effectiveness by the dioptrics component, the light beam of the configuration of arbitration can be obtained.
[0019] In order to attain the 1st or 2nd above-mentioned purpose, an optical element according to claim

5 is equipped with the macromolecule layer which has an azobenzene frame, and it is characterized by forming the 2nd irregularity in the front face of this 1st irregularity at spacing narrower than this 1st irregularity while the 1st irregularity which has a refraction function is formed in the front face of this macromolecule layer. In this optical element, while the refraction effectiveness is acquired with the 1st irregularity formed in the front face of a macromolecule layer, according to the configuration of the 2nd irregularity formed in the front face of this 1st irregularity, either [at least] the refraction effectiveness or the diffraction effect can be acquired.

[0020] In order to attain the 1st or 2nd above-mentioned purpose, an optical element according to claim 6 is equipped with the dioptrics component equipped with the 1st irregularity which has a refraction function, and the macromolecule layer which has an azobenzene frame on the front face of this 1st irregularity, and is characterized by forming the 2nd irregularity in the front face of this macromolecule layer at spacing narrower than said 1st irregularity. In this optical element, while the refraction effectiveness is acquired with the 1st irregularity in the front face of a dioptrics component, according to the configuration of the 2nd irregularity formed in the front face of this 1st irregularity, either [at least] the refraction effectiveness or the diffraction effect can be acquired.

[0021] In the above-mentioned optical element, it is desirable to be formed at spacing whose irregularity which has a refraction function is 5-100 micrometers, and it is desirable to be formed at spacing whose irregularity which has a diffraction function is 0.2-5 micrometers.

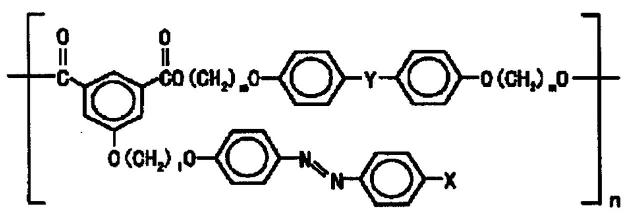
[0022] As for the glass transition point of a macromolecule, in the above-mentioned optical element, it is more desirable than a room temperature that it is either of the range of 20 degrees C - 50 degrees C an elevated temperature and near the room temperature.

[0023] In order to attain the 3rd above-mentioned purpose, an optical element according to claim 12 is characterized by forming the irregularity to which it has the macromolecule layer which has an azobenzene frame, and the glass transition point of this macromolecule is an elevated temperature from a room temperature, and has either [at least] a refraction function or a diffraction function on the front face of said macromolecule layer. From a room temperature, when it irradiates light when the glass transition point of a macromolecule is an elevated temperature, and it carries out induction of the irregularity, while it can carry out induction of the irregularity of sufficient depth, it can maintain the irregularity by which induction was carried out to stability. Consequently, easy and the refraction effectiveness which was excellent while it could form in stability and the degree of freedom of a design improved, and/or the outstanding diffraction effect can be acquired for the irregularity of sufficient depth on the surface of an optical element.

[0024] Moreover, in order to attain the 3rd above-mentioned purpose, it has the macromolecule layer which has an azobenzene frame, the glass transition point of this macromolecule is near the room temperature, and an optical element according to claim 13 is characterized by forming in the front face of said macromolecule layer the irregularity which has either [at least] a refraction function or a diffraction function. When irradiating light when the glass transition point of a macromolecule is near the room temperature, and carrying out induction of the irregularity, the induction of the irregularity of sufficient depth can be carried out. Consequently, while the irregularity of sufficient depth can be easily formed on the surface of an optical element and the degree of freedom of a design improves, the outstanding refraction effectiveness and/or the outstanding diffraction effect can be acquired.

[0025] Moreover, in order to attain the 3rd above-mentioned purpose, an optical element according to claim 14 is equipped with the macromolecule layer which has an azobenzene frame, is range whose glass transition point of this macromolecule is 20 degrees C - 50 degrees C, and is characterized by forming in the front face of said macromolecule layer the irregularity which has either [at least] a refraction function or a diffraction function. When irradiating light when the glass transition point of a macromolecule is the range which is 20 degrees C - 50 degrees C, and carrying out induction of the irregularity, while being able to carry out the induction of the irregularity of sufficient depth, the irregularity by which induction was carried out is maintainable to stability. Consequently, easy and the refraction effectiveness which was excellent while it could form in stability and the degree of freedom of a design improved, and/or the outstanding diffraction effect can be acquired for the irregularity of

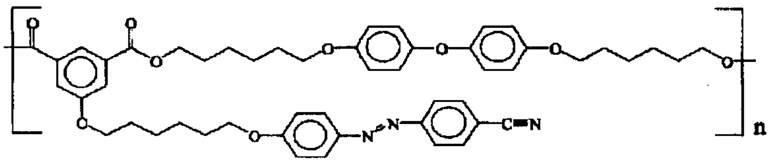
sufficient depth on the surface of an optical element.
[0026] In an optical element according to claim 12 to 14, the irregularity concerning the part which has a refraction function among the irregularity formed in the front face of a macromolecule layer can be formed at intervals of 5-100 micrometers. Moreover, as for the irregularity concerning the part which can form the irregularity concerning the part which has a diffraction function among the irregularity formed in the front face of a macromolecule layer at intervals of 0.2-5 micrometers, and has a diffraction function, it is desirable to be formed in a depth of 1 micrometers or more. Furthermore, it can have the 1st irregularity which is formed in the front face of a macromolecule layer and has a refraction function as irregularity formed in the front face of a macromolecule layer, and the 2nd irregularity which is formed in the front face of this 1st irregularity, and has a refraction function or a diffraction function. Moreover, the macromolecule layer may be formed in the front face of a dioptrics component.
[0027] In the above-mentioned optical element, the hologram may be recorded on the interior of a macromolecule layer. In this case, a diffraction function can be obtained by the hologram recorded on the interior.
[0028] In order to enable formation of deeper irregularity, as for the thickness of a macromolecule layer, it is desirable to be referred to as 1-10 micrometers. Moreover, as for a giant molecule, what has an azobenzene frame in a side chain is desirable, and what contains an aromatic hydrocarbon radical in a principal chain is more desirable. Also in these macromolecules, especially the polyester expressed with the following general formula (1) is desirable.
[0029]
[Formula 2]
一般式（1）



[0030] (Among a formula, X shows a cyano group, a methyl group, a methoxy group, or a nitro group, and Y shows the divalent connection radical by ether linkage, ketone association, or sulfone association.) l and m show the integer of 2-18, and n shows the integer of 5-500. In order to attain the 4th above-mentioned purpose, invention according to claim 25 is the manufacture approach of an optical element of manufacturing the optical element of this invention, and is characterized by irradiating the light which has predetermined intensity distribution, forming the irregularity according to these intensity distribution in the front face of a macromolecule layer established in the optical element, and manufacturing an optical element. In this case, it is desirable that the light to irradiate is the circular polarization of light. Moreover, predetermined intensity distribution can be made into the intensity distribution corresponding to a computer generated hologram or kino form, and the intensity distribution corresponding to the speckle pattern obtained from the diffuser.
[0031] By this manufacture approach, by irradiating the optical pattern of arbitration, the light which has the intensity distribution corresponding to a computer generated hologram or kino form, the light which has the intensity distribution corresponding to the speckle pattern obtained from the diffuser can form the irregularity of a request configuration in the front face of a macromolecule layer, and can manufacture simple and cheaply the optical element by which irregularity was formed in the front face of a macromolecule layer.
[0032] Moreover, in order to attain the 4th above-mentioned purpose, invention according to claim 29 is the manufacture approach of an optical element of manufacturing the optical element of this invention, and is characterized by irradiating body light and a reference beam on the front face of a macromolecule

layer established in the optical element, forming the irregularity according to the intensity distribution by the interference light of this body light and a reference beam, and manufacturing an optical element. In this case, as for body light and a reference beam, it is desirable that it is the circular polarization of light of the circumference of reverse mutually.
[0033] By this manufacture approach, by irradiating the optical pattern of arbitration, the interference fringe of light etc. can form the irregularity of a request configuration in the front face of a macromolecule layer, and can manufacture simple and cheaply the optical element by which irregularity was formed in the front face of a macromolecule layer, for example.
[0034] In order to attain the 5th above-mentioned purpose, the manufacture approach of an optical element duplicate object according to claim 31 Are the manufacture approach of an optical element duplicate object of manufacturing the duplicate object of the optical element of this invention, produce La Stampa for imprinting this irregularity using the irregularity formed in the front face of said optical element, and with the thermocompression bonding or injection molding using this La Stampa It is characterized by forming said irregularity and the irregularity of the same configuration in the front face of a resin ingredient, and manufacturing the duplicate object of said optical element.
[0035] Moreover, in order to attain the 5th above-mentioned purpose, an optical element duplicate object according to claim 32 is characterized by imprinting the irregularity formed in the front face of the optical element of this invention.
[0036] By the manufacture approach of the above-mentioned optical element duplicate object, La Stampa for imprinting this irregularity is producible using the irregularity formed in the front face of the optical element of this invention, such as performing mastering using the optical element of this invention, producing a metal master for example, and producing La Stampa based on this metal master. And by the approach suitable for mass production method, such as thermocompression bonding or injection molding using this La Stampa, the irregularity of the same configuration as the irregularity formed in the front face of a resin ingredient on the surface of the optical element can be formed, and the optical element of the shape of same surface type can be reproduced easily. For this reason, the optical element of the shape of complicated surface type can also be mass-produced easily. Moreover, the obtained optical element duplicate object demonstrates the outstanding refraction effectiveness and/or the outstanding diffraction effect like the optical element of this invention.
[0037]
[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained with reference to a drawing.
[Ingredient of a polymer carrier or a giant-molecule layer] The polymeric materials used for the optical element of this invention are giant molecules (an "azo polymer" is called hereafter) which have an azobenzene frame. This azobenzene frame shows the photoisomerization cycle of a transformer-cis--transformer.
[0038] this invention -- setting -- the inside of these azo polymer -- a glass transition point Tg -- a near room temperature -- a hot azo polymer is somewhat more desirable especially preferably than a room temperature. The former, Photofabrication of surfaces for holograms, As indicated by Sukant Tripathy, Dong-Yu Kim, LianLi, and Jayant Kumar, and CHEMTECH MAY (1998) pp.34-40. Although the azo polymer 100 degrees C or more was used for surface relief formation, a glass transition point Tg this invention person etc. is that a glass transition point Tg uses the azo polymer near the room temperature for a record medium, and, as for deep relief structure, easy and being obtained by stability raised sharply the degree of freedom of a design of a header and an optical element.
[0039] Moreover, the macromolecule which contains an azobenzene frame in a side chain from a viewpoint of the molecular structure is desirable, and the macromolecule which contains an aromatic hydrocarbon radical in a principal chain is more desirable. Also in these, especially the polyester expressed with the above-mentioned general formula (1) is desirable.
[0040] The example of the azo polymer which can be used by this invention is shown below.
[0041]
[Formula 3]

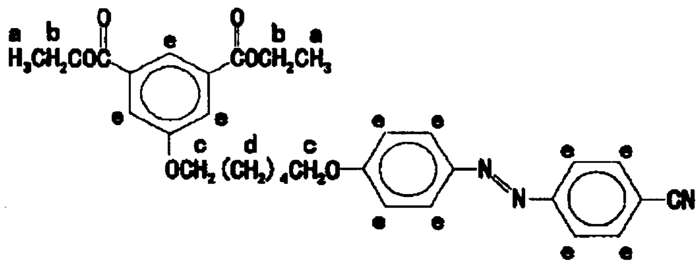
アゾポリマー (1)



[0042] The polyester (azo polymer (1)) which has a cyano azobenzene in the above-mentioned side chain is M.Sato's and others "Synthesis and properties of polyesters having cyanoazobenzene units in the side chain", and Macromol.Rapid. Commun. It is reported to 15 and 21-29 (1994), and can compound by the approach indicated by this reference. Next, the synthesis procedure of this azo polymer (1) is explained.
[0043] (Composition of a 4-hydroxy-4'-cyano azobenzene) NaNO2 water solution (NaNO2150g, 750ml of pure water) was dropped, stirring two mols (236.3g) of 4-amino benzonitriles, 600ml (12Ns) of HCl (s), and 600ml of pure water in an ice bath (step 1). Two mols (191.8g) of phenols and two mol (112.3g) of KOH(s) are quickly dissolved in about 2l. pure water, and the product of step 1 was dropped and was made to react. After reaction termination, after ****(ing) a product by suction filtration, reduced pressure drying was washed and carried out with pure water. The obtained product was made to recrystallize with a methanol and the crystal of 1.3 mols of 4-hydroxy-4'-cyano azobenzenes (292.3g, 65.5% of yield) was obtained.
[0044] (Composition of a 4-(6-BUROMO hexyloxy)-4'-cyano azobenzene) 0.2 mols (44.6g) of 4-hydroxy-4'-cyano azobenzenes, 1, two mols (488.1g) of 6-dibromo hexanes, 31.45 mols (200.4g) of K2COs, and 800ml of acetones are put into a 2l. three-neck flask, and it flowed back for 20 hours and was made to react using a water bus. After cooling to a room temperature, a by-product and superfluous K2CO3 were filtered and removed. After condensing the obtained filtrate to about about 1 / 2 using a rotary evaporator, it was left in the freezer and it was crystallized. After ****(ing) the depositing crystal by suction filtration, reduced pressure drying was washed and carried out by n-hexane (0.117 mols (45.3g, 58.6% of yield)). Furthermore, the obtained rough crystal was made to recrystallize in ethanol, and 0.094 mols (36.3g, 47.0% of yield) of 4-(6-BUROMO hexyloxy)-4'-cyano azobenzenes were obtained.
[0045] (Composition of 5-hydroxy isophthalic acid diethyl ester) One mol (182.4g) of 5-hydroxy isophthalic acid, 1500ml of ethanol, and 10ml of concentrated sulfuric acid are put into a 2l. three-neck flask, and it flowed back for 24 hours and was made to react using a water bus. After condensing reaction mixture using the rotary evaporator and filling NaHCO3 water solution with concentration liquid, reduced pressure drying of the product was ****(ed) and carried out, and 0.096 mols (228.8g, 96.0% of yield) of 5-hydroxy isophthalic acid diethyl ester were obtained. Furthermore, the obtained product was made to recrystallize in ethanol and reduced pressure drying was carried out under heating (50-60 degrees C).
[0046] (Side-chain section monomer: 5 -(4-cyanobenzene azo phenoxy hexyloxy)- Composition of isophthalic acid ethyl ester) 0.08 mols (30.9g) of 4-(6-BUROMO hexyloxy)-4'-cyano azobenzenes, 0.08 mols of 5-hydroxy isophthalic acid diethyl ester, 30.12 mols (16.58g) of K2COs, and 400ml of acetones are put into a 1l. three-neck flask, and it flowed back for 24 hours and was made to react using a water bus. About 4l. pure water was filled with reaction mixture after radiationnal cooling, and reduced pressure drying of the precipitate was filtered, taken out and carried out (0.071 mols (38.8g, 89.2% of yield)). 5 which is made to recrystallize with an acetone after that and becomes a side-chain section monomer -(4-cyanobenzene azo phenoxy hexyloxy)- The crystal of 0.058 mols of isophthalic acid ethyl ester (31.4g, 72.2% of yield) was obtained. The melting point of the obtained crystal is 99.0 degrees C, and had the absorption peak in 364.2nm.
[0047] A FTIR spectrum and 1 H-NMR performed identification of a side-chain section monomer. The measurement result of FTIR is shown below.
FTIR(KBr): 2947.7cm-1 (CH telescopic motion), 2227.4cm-1(CN)1713.4cm-1 (ester C=O), 1599.7cm-

1 (C=C), 1580cm-1 (N=N), 1244.8cm-1 (C-O-C)
Moreover, the result of 1 H-NMR analysis of a spectrum is shown in the following table 1.
[0048]
[Table 1]

側鎖部モノマー^{1}H NMR スペクトルの化学シフト ($CDCl_3$)

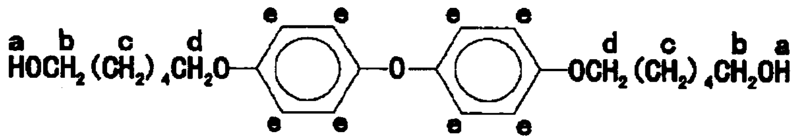


diethyl-5-(4-cyanobenzeneazophenoxyhexyloxy) isophthalate
(543.61)

水素の位置	a	b	c	d	e		
δ (ppm)	1.40 (6H)	4.39 (4H)	4.07 (4H)	1.58～1.88 (8H)	7.00～7.03 (2H)	7.73～7.79 (5H)	7.91～7.94 (4H)

[0049] (Principal-chain section monomer: Composition of the bis(4-hydronalium hexyloxy phenyl) ether) 0.3 mols (60.66g) of 4 and 4'-dihydroxy diphenyl ether, 0.66 mols (90.16g) of 6-chloro-1-hexanols, 30.7 mols (97g) of K2COs, and 250ml of N.N-dimethylformamide were mixed, and it heated at 160 degrees C using the oil bath, and was made to react for 24 hours. Then, the water containing a small amount of hydrochloric acid was filled with reaction mixture, the product was ****(ed) by suction filtration, carried out reduced pressure drying, and the bis(4-hydronalium hexyloxy phenyl) ether was obtained. Furthermore, the obtained product was made to recrystallize from a water-N.N-dimethylformamide system partially aromatic solvent, and the crystal of the bis(4-hydronalium hexyloxy phenyl) ether was obtained almost quantitatively. The melting point of the obtained crystal was 119 degrees C.
[0050] A FTIR spectrum and 1 H-NMR performed identification of a principal chain section monomer. The measurement result of FTIR is shown below.
FTIR(KBr, JASCO FT/IR -230): 3312.1cm-1(OH)2936.1cm-1 (CH telescopic motion), 1505.2cm-1 (aromatic series), 1241.9cm-1 (C-O-C)
Moreover, the result of 1 H-NMR analysis of a spectrum is shown in the following table 2.
[0051]
[Table 2]

主鎖部モノマー^{1}H NMRスペクトルの化学シフト ($CDCl_3$)

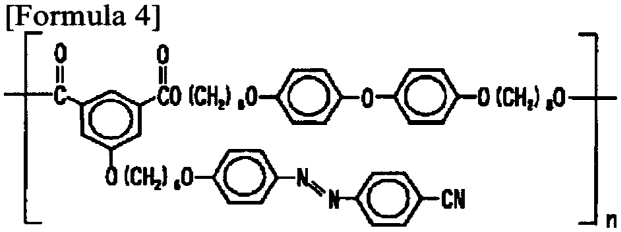


bis(4-hydrohexyloxyphenyl)ether
(402.52)

水素の位置	a	b	c	d	E
δ (ppm)	1.30 (2H)	3.67 (4H)	1.44~1.82 (16H)	3.93 (4H)	6.82~6.92 (8H)

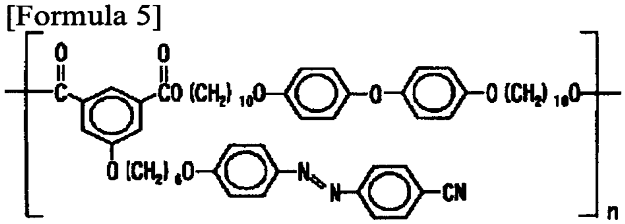
[0052] (Melt polycondensation of the polyester which has an azobenzene in a side chain) Side-chain section monomer: 5 -(4-cyanobenzene azo phenoxy HEKISHINOKISHI)- 0.01 mols (5.4361g) of isophthalic acid ethyl ester, 0.01 mols (4.0253g) of principal chain section monomer:bis(4-hydronalium hexyloxy phenyl) ether, and 0.1g of acetic-anhydride zinc were put into the 300ml three-neck flask, and it was made to react under nitrogen-gas-atmosphere mind according to the following step of 1-4.
1) Decompressed to reaction 210Torr (1.33x103Pa) at about 160 degrees C for 2 hours, chloroform was made to dissolve after the 2-hour reaction above-mentioned reaction termination and reaction mixture in 180 degrees C and 2 - 5Torr (0.27x103 to 0.67x103Pa) over reaction 3 30 minutes for 20 minutes by the temperature up and reduced pressure 4 180 degree C, and 2 - 5Torr (0.27x103 to 0.67x103Pa), and it poured into the methanol. Precipitate was filtered and taken out, after carrying out heating washing with pure water, with the methanol, heating washing was carried out, reduced pressure drying was carried out, and the polyester which has a cyano azobenzene in a side chain was obtained almost quantitatively.
[0053] The DSC (differential scanning calorimeter) curve of the azo polymer (1) compounded by the above-mentioned approach to drawing 1 is shown. Glass transition temperature Tg was 38 degrees C, and the melting point Tm was 65 degrees C. Moreover, according to polarization microscope observation, the liquid crystal phase was a macromolecule which does not exist but has a birefringence in a solid state.
[0054] Next, the record medium which has the macromolecule layer which consists of an azo polymer (1) on a substrate was created. First, the azo polymer (1) compounded by the above-mentioned approach was melted by the concentration of 0.8g/ml with chloroform, and carried out the spin coat on the washed glass substrate (1000rpm, 20 seconds). After making it dry, it heated and quenched to the temperature which becomes an isotropic phase, and the macromolecule layer which consists of an azo polymer (1) was formed. It checked that the macromolecule layer formed of polarization microscope observation was the isotropic amorphous film. Moreover, it was 1.5 micrometers when thickness was measured using the sensing-pin-type surface roughness meter.
[0055] The surface relief hologram was formed using this record medium, and the relation between the concavo-convex depth (relief depth) and exposure energy was investigated. If in charge of formation of a surface relief hologram, while branching to two light waves and making this into body light and a reference beam using the 515nm oscillation line of an Ar ion laser, each polarization was mutually made into the circular polarization of light of the circumference of reverse. Exposure reinforcement was made into 0.5 W/cm2. The crossed axes angle of two light waves was adjusted so that spacing of the grating formed might become two kinds which are 1 micrometer and 10 micrometers, and the situation of relief development was investigated. A result is shown in drawing 2 .
[0056] When exposure energy increased so that drawing 2 might show, the relief depth also increased. Moreover, the irregularity of the depth exceeding 1 micrometer has been formed in the grating whose spacing is 10 micrometers. Moreover, the grating of 1-micrometer spacing has formed irregularity with a

smaller than it depth of about 0.25 micrometers.
[0057] Thus, in the record medium using an azo polymer (1), induction of the relief deeper than before can be carried out. Since Tg of an azo polymer is near the room temperature, this is conjectured to be for the molecule migration by optical exposure to take place easily. If the azo polymer of Tg lower than a room temperature is used, although induction of the deep relief will be carried out on the other hand at the time of an optical exposure, the configuration is not maintained after optical cutoff and the optical element with irregularity deep as a result cannot be realized. Therefore, deep relief structures are easy and the point acquired by stability, and Tg somewhat higher than a room temperature and the azo polymer which shows Tg of the range of 20 degrees C - 50 degrees C preferably are suitable for this invention as described above.
[0058] Next, when changed various thickness of the macromolecule layer which consists of an azo polymer (1), two or more record media were produced, the surface relief hologram was formed about each record medium and the relation between the relief depth and exposure energy was investigated, it was checked that induction of the irregularity of the magnitude same in the range whose thickness of an azo polymer is 1 micrometer - 10 micrometers as the case where it is shown in drawing 2 is carried out.
[0059] Although two or more reports of the example by which induction of the irregularity was carried out to the azo polymer layer of 100nm of thickness numbers by the about dozens to 100-micrometer thin film are carried out conventionally, the example which carried out induction of the deep relief structure to the thick azo polymer layer exceeding several micrometers is not reported. In this invention, also when thickness of an azo polymer layer was thickened with 1micro - 10 micrometers, it was shown clearly that the induction of the irregularity of several micrometers can be effectively carried out from hundreds of nm. That is, it found out that very big surface relief structure was generable by using for a record medium the azo polymer which has suitable Tg, making the thickness comparatively thick, and recording a hologram as described above. And the degree of freedom of a design of an optical element was able to be sharply raised by applying this to an optical element.
[0060] The example (a chemical structure type and its Tg) of other azo polymers which can be used by this invention is shown below. These azo polymers are compoundable by the same approach as an azo polymer (1).
[0061]
[Formula 4]



Tg=26.8℃, Tm=56.4℃
アゾポリマー(2)

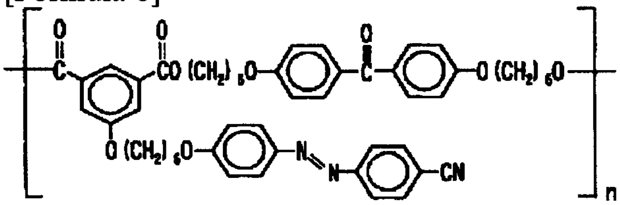
[0062]
[Formula 5]



Tg=23.9℃, Tm=62.7℃
アゾポリマー(3)

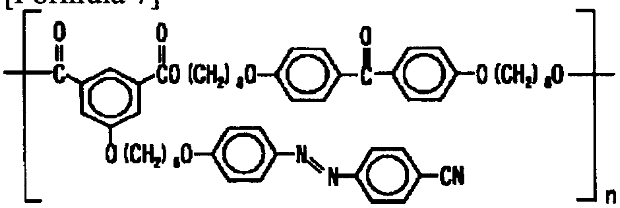
[0063]

[Formula 6]



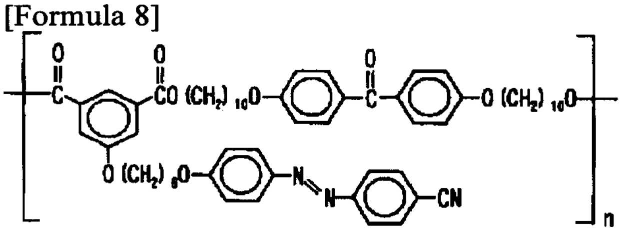
Tg=48.5℃, Tm=82.2℃
アゾポリマー(4)

[0064]
[Formula 7]



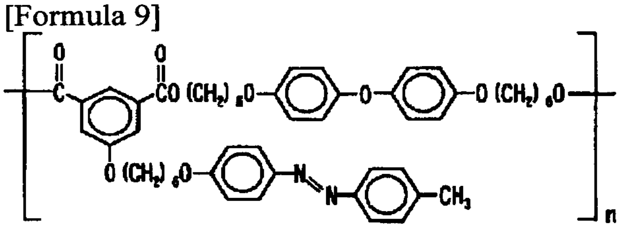
Tg=37.8℃, Tm=70.2℃
アゾポリマー(5)

[0065]
[Formula 8]



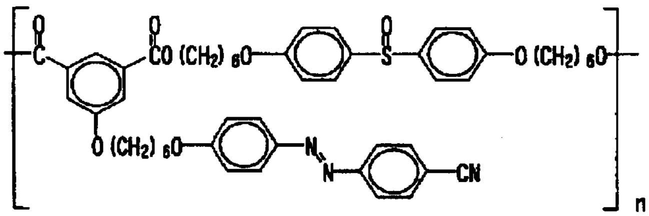
Tg=33.1℃, Tm=68.5℃
アゾポリマー(6)

[0066]
[Formula 9]



Tg=38.0℃
アゾポリマー(7)

[0067]
[Formula 10]



アゾポリマー(8)

[0068] As above-mentioned, Tg of the illustrated azo polymer is within the limits of 20 to 50 degrees C, and it was checked also in the relief formation experiment that the induction of the deep irregularity can be carried out like an azo polymer (1).
[0069] [Gestalt of an optical element] As shown in drawing 3 (a), the optical element of this invention can be constituted so that it may have the azo polymer support 10. In addition, azo polymer support consists of only azo polymer layers. The irregularity of the predetermined configuration which has either [at least] a refraction function or a diffraction function is formed in surface 10a of the azo polymer support 10. This irregularity can be formed by irradiating the light of the predetermined wavelength which carries out induction of the isomerization of an azo polymer to surface 10a of the azo polymer support 10 which is a record medium by predetermined intensity distribution.
[0070] Moreover, the optical element of this invention may consist of bases 12, such as a glass substrate and a plastic plate, and an azo polymer layer 14 formed in this base 12 front face, as shown in drawing 3 (b). Similarly, the irregularity of the predetermined configuration which has either [at least] a refraction function or a diffraction function is formed in surface 14a of the azo polymer layer 14. When such irregularity irradiates the light of the predetermined wavelength which carries out induction of the isomerization of an azo polymer to surface 14a of the azo polymer layer 14 of this record medium by predetermined intensity distribution, the irregularity of a predetermined configuration is formed in surface 14a.
[0071] The record medium equipped with the above-mentioned azo polymer layer 14 is producible by carrying out the cast of the chloroform solution of an azo polymer for example, on the washed base 12, and drying. Moreover, the spin coat of the azo polymer solution may be carried out on a base 12, and the azo polymer layer 14 may be formed. Moreover, when using the film-like base 12, an azo polymer ingredient can be pasted up on a base 12 with a hotpress, and the azo polymer layer 14 can also be formed.
[0072] The above-mentioned irregularity has either a diffraction function or a refraction function with spacing (concavo-convex pitch) in which irregularity is formed. When considering a diffraction function, a concavo-convex pitch is equivalent to a lattice spacing lambda. In the wavelength of incident light, if the refractive index of lambda and a medium is set to n and an angle of diffraction (2 light-wave crossed axes angle of hologram record) is set to theta, a lattice spacing lambda will be given by the following formula.
[0073]
[Equation 1]

$$\Lambda = \frac{\lambda}{2n\,sin\left\{\frac{1}{2}sin^{-1}\left(\frac{1}{n}sin\,\theta\right)\right\}}$$

[0074] For example, if it is the wavelength of lambda= 600nm of incident light, and the refractive index n= 1.5 of a medium (azo polymer), as for an angle of diffraction theta, a lattice spacing lambda will become small with 0 degree - 7 degrees in 5 micrometers or more, and, as for an angle of diffraction theta, a lattice spacing lambda will become large with 90 degrees in 0.5 micrometers. that is, when a concavo-convex pitch is to some extent large, an angle of diffraction mainly has the operation by

refraction small, and a concavo-convex pitch becomes narrow -- it is alike, and it follows and comes to have an effective (an angle of diffraction -- large) diffraction function. Although extent of a diffraction function and a refraction function changes also with the wavelength lambda of incident light, and the refractive indexes of an azo polymer somewhat strictly this passage, when a concavo-convex pitch is roughly formed at spacing which is 5-100 micrometers, that irregularity has a refraction function, and when formed at spacing whose concavo-convex pitch is 0.2-5 micrometers, you may think that that irregularity has a diffraction function. Moreover, as for the above-mentioned irregularity, diffraction efficiency changes with the depth (concavo-convex depth) in which irregularity is formed. As aforementioned, generating of zero-order light decreases as the concavo-convex depth becomes deep, and diffraction efficiency improves.

[0075] In addition, a concavo-convex pitch is spacing of adjoining heights and heights, and the concavo-convex depth is the gap of the maximum heights and the maximum crevice. These irregularity pitch and the concavo-convex depth can be measured from the observation image by AFM (atomic force microscope). What is necessary is just to ask for the average or the distributed range like a speckle pattern, when a concavo-convex pitch is not fixed. Moreover, based on the above-mentioned relational expression, it can also ask for a concavo-convex pitch from the refractive index n and angle of diffraction theta of wavelength lambda and an azo polymer of incident light.

[0076] [Gestalt of the 1st operation] The optical element of the gestalt of this operation forms in the front face of azo polymer support the irregularity (the 1st irregularity) which functions as a lenticular lens, and forms in the front face of this irregularity the irregularity (the 2nd irregularity) which has a diffraction function at spacing narrower than this irregularity. In addition, the lenticular lens has the structure shown in drawing 4 (a).

[0077] First, as shown in drawing 5 , the light wave 18 which has light and darkness (optical intensity distribution shown in drawing 6) corresponding to the configuration of a lenticular lens with the space optical modulator 16 is generated, and image formation of this light wave 18 is carried out to surface 10a of the azo polymer support 10 with lenses 20 and 22. Thereby, as shown in drawing 7 (a), irregularity 24 is formed in surface 10a of the azo polymer support 10 so that it may have an operation of a lenticular lens.

[0078] As shown in drawing 7 (a), if incidence of the light (incident light) 26 is carried out, the diffused light 28 can be acquired from the side by which irregularity 24 was formed in the azo polymer support 10 in which this irregularity 24 was formed by the refraction function of irregularity 24. The beam profile of the diffused light 28 is shown in drawing 7 (b). the diffusion property of the lenticular lens shown in drawing 4 (b), and abbreviation -- it turns out that it has the same diffusion property.

[0079] Next, as shown in drawing 8 , it branches to two light waves and a laser beam is irradiated as the body light 30 and a reference beam 32 at surface 10a in which the irregularity 24 of the azo polymer support 10 was formed, respectively. The body light 30 and a reference beam 32 are mutually taken as the circular polarization of light of the circumference of reverse. A surface relief hologram is recorded efficiently by this, and detailed irregularity is formed in the front face of the irregularity 24 of the azo polymer support 10.

[0080] If it designs so that the primary plus light 34, the primary minus light 36, and the zero-order light 38 may be diffracted equally when incident light 26 carries out incidence of the surface relief hologram, as shown in drawing 9 (a) When incidence of the incident light 26 is carried out to the azo polymer support 10 from the side in which irregularity 24 was formed, the diffused light (the primary plus light 34, the primary minus light 36, and zero-order light 38) of trifurcation is generated, and the beam of a diffusion angle shown in drawing 9 (b) can be obtained.

[0081] While the same refraction effectiveness as a lenticular lens is acquired with the irregularity formed in the front face of azo polymer support by the optical element of the gestalt of this operation as above, the diffraction effect can be acquired with the detailed irregularity formed in the front face of this irregularity. Moreover, since both the refraction effectiveness and the diffraction effect are acquired, a complicated beam profile can be obtained according to an application. Furthermore, by irradiating the optical pattern of arbitration and carrying out induction of the irregularity of a request configuration to a

front face, irregularity can be formed in a front face and an optical element can be manufactured simple and cheaply.
[0082] [Gestalt of the 2nd operation] It forms an azo polymer layer in the concavo-convex (the 1st irregularity) field of a lenticular lens, and forms the irregularity (the 2nd irregularity) which has a diffraction function at spacing narrower than the irregularity of a lens on the front face of this azo polymer layer further while the lenticular lens which is a dioptrics component as a base is used for the optical element of the gestalt of this operation.
[0083] First, as shown in drawing 10 , the coat of the azo polymer is carried out to homogeneity, and the azo polymer layer 14 is formed in the concave convex of lenticular lens 12A of a quartz. The azo polymer layer 14 is formed along with the irregularity of a lenticular lens 12A front face. This lenticular lens has the structure shown in drawing 4 (a), and as shown in drawing 4 (b), it diffuses incident light so that mesial magnitude full width may become 10 degrees.
[0084] Next, as shown in drawing 11 , it branches to two light waves and a laser beam is irradiated as the body light 30 and a reference beam 32 at surface 14a of the azo polymer layer 14, respectively. The body light 30 and a reference beam 32 are mutually taken as the circular polarization of light of the circumference of reverse. A surface relief hologram is recorded efficiently by this, and detailed irregularity is formed in surface 14a of the azo polymer layer 14.
[0085] If it designs so that the primary plus light 34, the primary minus light 36, and the zero-order light 38 may be diffracted equally when incident light 26 carries out incidence of the surface relief hologram, as shown in drawing 12 (a) When incidence of the incident light 26 is carried out to the azo polymer layer 14 from the side in which irregularity 24 was formed, the diffused light (the primary plus light 34, the primary minus light 36, and zero-order light 38) of trifurcation is generated, and the beam of a diffusion angle shown in drawing 12 (b) can be obtained.
[0086] While the refraction effectiveness is acquired with a lenticular lens by the optical element of the gestalt of this operation as above, the diffraction effect can be acquired with the detailed irregularity formed in the front face of an azo polymer layer. Moreover, since both the refraction effectiveness and the diffraction effect are acquired, a complicated beam profile can be obtained according to an application. Furthermore, by irradiating the optical pattern of arbitration and carrying out induction of the irregularity of a request configuration to a front face, irregularity can be formed in a front face and an optical element can be manufactured simple and cheaply.
[0087] In addition, although the example which uses the lenticular lens of a quartz above was explained, as long as it is insoluble as a dioptrics component to the solvent which dissolves the above-mentioned azo polymer, the thing of what kind of medium may be used, and what kind of forms, such as the spherical surface, the aspheric surface, and a concave lens, are sufficient also as the configuration.
[0088] [Gestalt of the 3rd operation] It forms an azo polymer layer in the concavo-convex (the 1st irregularity) field of a lenticular lens, and forms the irregularity (the 2nd irregularity) which has a refraction function at spacing narrower than the irregularity of a lens on the front face of this azo polymer layer further while the lenticular lens which is a dioptrics component as a base is used for the optical element of the gestalt of this operation.
[0089] First, like the gestalt of the 2nd operation, the coat of the azo polymer is carried out to homogeneity, and the azo polymer layer 14 is formed in the concave convex of lenticular lens 12A of a quartz. The azo polymer layer 14 is formed along with the irregularity of a lenticular lens 12A front face. This lenticular lens has the structure shown in drawing 4 (a), and as shown in drawing 4 (b), it diffuses incident light so that mesial magnitude full width may become 10 degrees.
[0090] Next, the speckle pattern from a diffuser is imprinted to surface 14a of the azo polymer layer 14 using the speckle imprint optical system shown in drawing 13 . That is, the diffused light 50 by which is made to carry out incidence of the laser beam 42 from the light source 40 to a diffuser 48 as the circular polarization of light 46 with the quarter-wave length plate 44, and outgoing radiation is carried out behind a diffuser 48 is irradiated at surface 14a of the azo polymer layer 14. Thereby, as shown in drawing 14 , the irregularity 52 according to a speckle pattern is formed in the azo polymer layer 14.
[0091] The diffusion property of the horizontal and the perpendicular direction of this optical element is

shown in drawing 15 . Horizontally it is the direction where the cylindrical side of a lenticular lens is located in a line, and, perpendicularly, is the direction which intersects perpendicularly with this here. A continuous line shows the diffusion property after a speckle pattern imprint, and a dotted line shows the diffusion property before a speckle pattern imprint. The direction of the optical element which formed the irregularity 52 according to a speckle pattern in the azo polymer layer 14 excels [whenever / diffusion angle] in the diffusion property greatly so that drawing 15 may show.
[0092] The more excellent refraction effectiveness can be acquired being able to acquire the refraction effectiveness and pressing down the thickness of a component also with the detailed irregularity formed in the front face of an azo polymer layer, while the refraction effectiveness is acquired with a lenticular lens by the optical element of the gestalt of this operation as above. Moreover, by irradiating the optical pattern of arbitration and carrying out induction of the irregularity of a request configuration to a front face, irregularity can be formed in a front face and an optical element can be manufactured simple and cheaply.
[0093] In addition, although the example which uses the lenticular lens of a quartz above was explained, other dioptrics components may be used like the gestalt of the 2nd operation.
[0094] Moreover, although the example which imprints the speckle pattern obtained from the diffuser above was explained, the light of the intensity distribution corresponding to a computer generated hologram or kino form is irradiated, and the irregularity according to these intensity distributions can also be formed. A computer generated hologram is a hologram recorded with the light of the intensity distribution which calculate the interference fringe produced by body light and the reference beam, and are equivalent to a count result. A computer generated hologram is explained in full detail in an example. Kino form is reinforcement or not the polarization direction but the hologram which recorded phase distribution.
[0095] When mass-producing the [manufacture approach suitable for mass production method], next the duplicate object of the optical element of this invention, the suitable manufacture approach is explained. The optical element of this invention is characterized by forming in the front face of azo polymer support or an azo polymer layer the irregularity of the predetermined configuration which has either [at least] a refraction function or a diffraction function as above-mentioned. Therefore, the optical element equipped with the shape of same toothing can be reproduced by imprinting the irregularity formed in the front face.
[0096] For example, the metal mold (metal master) of the negative of this optical element is producible by performing electric conduction processing to an optical element by golden vacuum evaporationo or electroless deposition, and performing electrocasting, such as nickel, like the production process of a compact disk, using the optical element which irradiated the optical pattern of arbitration and carried out induction of the irregularity of a request configuration to the front face of azo polymer support or an azo polymer layer. Based on this metal mold, a pattern can be imprinted into resin ingredients, such as an acrylic, Pori Karr Nate, and polyester, and a duplicate object (optical element) can be obtained by thermocompression bonding, injection-molding processing, etc. into them.
[0097] Below, the production process of a duplicate object is explained. First, like the gestalt of the 1st operation, as shown in drawing 16 (A), while irregularity 24 is formed in surface 10a of the azo polymer support 10, the optical element by which detailed irregularity was formed in the front face of irregularity 24 is produced. Next, as shown in drawing 16 (B), gold is vapor-deposited to surface 10a in which the irregularity 24 and the detailed irregularity of this optical element were formed, and the thin film deposit 54 is formed in it (mastering process).
[0098] Next, the metal master 56 which formed the metal master 56 of predetermined thickness by nickel electrocasting on the thin film deposit 54, and was formed by drawing 16 (D) is exfoliated from the thin film deposit 54 in drawing 16 (C). By drawing 16 (E), a mother 58 is formed by nickel electrocasting on this metal master 56 that exfoliated, and a mother 58 is exfoliated from a metal master 56 in drawing 17 (A). By drawing 17 (B), La Stampa 60 is formed by nickel electrocasting on the mother 58 who exfoliated, by drawing 17 (C), it exfoliates from a mother 58 and La Stampa 60 completes La Stampa 60 (La Stampa making process). This La Stampa 60 is equipped with the

irregularity corresponding to the irregularity 24 and the detailed irregularity which were formed in surface 10a of the azo polymer support 10.

[0099] Next, as shown in drawing 17 (D), the polyester resin 65 which attached and carried out thermofusion of this La Stampa 60 to the injection molding machine which consists of a cover half 62 and a migration mold 64 is poured in by the high-pressure force from an inlet (not shown), and injection molding is performed. Finally, as shown in drawing 17 (E), the temperature of an injection molding machine falls and the optical element 66 made of polyester resin is taken out in the place which resin hardened. The irregularity of the same configuration as the irregularity 24 and the detailed irregularity which were formed in surface 10a of the azo polymer support 10 is formed in surface 66a of the taken-out optical element 66 (imprint forming cycle).

[0100] By the above-mentioned approach, since La Stampa is produced from an optical element and a duplicate object is manufactured with thermocompression bonding or injection molding using this La Stampa, it is suitable for producing a duplicate object in large quantities.

[0101] As explained above, the optical element of this invention can acquire the outstanding refraction effectiveness and/or the outstanding diffraction effect with the irregularity formed in the front face of the macromolecule layer which consists of an azo polymer. Since it has the function of both a diffraction component and a refraction component in acquiring the diffraction effect especially in addition to the refraction effectiveness, it is effective in obtaining the beam of the configuration of arbitration, and application of [besides an optical bus system / spectroscope / an image formation optical element, a super resolution lens, / variably] can be expected.

[0102] Moreover, when using the azo polymer near the room temperature which has the desirable glass transition point of an elevated temperature [room temperature], easy and the refraction effectiveness which was excellent while it could form in stability and the degree of freedom of a design improved, and/or the outstanding diffraction effect can be acquired for the irregularity of sufficient depth for the front face of a macromolecule layer.

[0103] Moreover, according to the manufacture approach of the optical element of this invention, by irradiating the optical pattern of arbitration, such as an interference fringe of light, a speckle pattern, and a computer generated hologram, induction of the complicated irregularity can be carried out easily, and an optical element can be produced that it is simple and cheaply. Furthermore, according to the manufacture approach of the optical element duplicate object of this invention, it is also possible to produce La Stampa based on this optical element, and to manufacture a duplicate object in large quantities using La Stampa. Moreover, according to the obtained optical element duplicate object, the outstanding refraction effectiveness and/or the outstanding diffraction effect can be acquired like the optical element of this invention.

[0104] In addition, although the example which prepares above the irregularity which has a refraction function for dioptrics components, such as a lens, and the irregularity which has a diffraction function was explained, the irregularity which has a refraction function in other optical elements, such as a polarizing plate, a wavelength plate, and a reflecting plate, and the irregularity which has a diffraction function can also be prepared.

[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

EXAMPLE

[Example] Next, although an example explains this invention to a detail further, this invention is not limited to the following examples.
(Example 1) This example explains the example which produced the optical element suitable as an optical diffusion branching component used for an optical data bus and a signal processor which are indicated by JP,10-282371,A with reference to drawing 18 and drawing 19 .
[0106] As an azo polymer, the polyester (instantiation compound: azo polymer (2)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (2) is 26.8 degrees C, and is suitable for this invention. This azo polymer (2) was applied to transparence glass substrate 12B by the thickness of 1.5 micrometers, and the record medium equipped with the azo polymer layer 14 was produced.
[0107] While irradiating surface 14a of the azo polymer layer 14 as a body light 30, the space optical modulator 16 having generated the light wave (optical intensity distribution shown in drawing 18 (a)) which spread horizontally using the optical system shown in drawing 18 (b), and condensing this light wave with a lens 70, the parallel reference beam 32 was irradiated by the beam splitter 72 at coincidence. The body light 30 and a reference beam 32 were mutually set as the circular polarization of light of the circumference of reverse. A surface relief hologram is recorded efficiently by this, and detailed irregularity is formed in surface 14a of the azo polymer layer 14. The concavo-convex pitch was 0.8-2.0 micrometers.
[0108] The condition of surface 14a is expanded and shown in drawing 19 . As shown in drawing 19 , induction of the surface relief hologram 1 micrometers or more was carried out for the concavo-convex depth by recording with sufficient exposure energy. Consequently, when incidence of the light was carried out to the obtained optical element, the zero-order diffracted light hardly appeared, but the diffused light of the optical intensity distribution shown in drawing 18 (a) was able to be acquired. Therefore, this optical element is suitable as an optical diffusion branching component for above-mentioned optical data buses.
[0109] (Example 2) This example explains the optical diffusion branching component used suitable for an optical data bus and a signal processor which are indicated by JP,10-282371,A, and its production approach with reference to drawing 20 - drawing 22 .
[0110] As an azo polymer, the polyester (instantiation compound: azo polymer (3)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (3) is 48.5 degrees C, and is suitable for this invention. This azo polymer (3) was applied to transparence glass substrate 12B by the thickness of 8.0 micrometers, and the record medium equipped with the azo polymer layer 14 was produced.
[0111] Drawing 20 is the optical intensity distribution for carrying out induction of the lenticular lens of a random pitch to the front face of an azo polymer layer in 5-100 micrometers. The light wave of the optical intensity distribution shown in drawing 20 was generated using the optical system shown in drawing 5 , and the front face of an azo polymer layer was irradiated. The light wave at this time was set as the circular polarization of light. Irregularity is formed in the front face of an azo polymer layer so

that this may have an operation of the above-mentioned lenticular lens.
[0112] The concavo-convex depth shows the surface state of an azo polymer layer to drawing 21 . By recording with sufficient exposure energy, as shown in drawing 21 , induction of the surface relief hologram whose concavo-convex depth is a maximum of 1.2 micrometers was carried out.
[0113] The diffusion property of the horizontal and the perpendicular direction of this optical element is shown in drawing 22 . Horizontally, there is no zero-order transmitted light and the beam has diffused it in homogeneity so that drawing 22 may show. On the other hand, since the beam did not spread perpendicularly, this optical element showed good non-isotropic diffusion. That is, in this example, the dioptrics component which equipped the front face with the shape of toothing of arbitration can be produced easily, and a desired diffusion property can be acquired.
[0114] (Example 3) By this example, a speckle pattern is imprinted on the front face of an azo polymer layer from a diffuser, irregularity is formed in it, and the example which produced the optical element is explained.
[0115] When volume hologram record of the speckle pattern which a diffuser is made to penetrate coherent light and is produced behind a diffuser is carried out, it is known that the hologram itself shows a diffusion property. For example, the hologram diffuser by which the diffusion boundary where a refractive index changes gently using this effectiveness was recorded on JP,4-299303,A is indicated. On the other hand, this example explains how to record not refractive-index change but a speckle pattern on the front face of a direct azo polymer layer as irregularity.
[0116] As an azo polymer, the polyester (instantiation compound: azo polymer (5)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (5) is 37.8 degrees C, and is suitable for this invention. This azo polymer (5) was applied to transparence glass substrate 12B by the thickness of 3.0 micrometers, and the record medium equipped with the azo polymer layer 14 was produced.
[0117] Next, the speckle pattern from a diffuser is imprinted to surface 14a of the azo polymer layer 14 using the speckle imprint optical system shown in drawing 23 . That is, incidence of the laser beam 42 from the light source 40 was carried out to the diffuser 48 as the circular polarization of light 46 with the quarter-wave length plate 44, using 488nm of oscillation lines of an Ar ion laser as the light source 40. The non-isotropic-diffusion object which generates the diffused light of an ellipse as a diffuser 48 was used. The record medium has been arranged behind [5mm] a diffuser 48, and the diffused light 50 by which outgoing radiation is carried out from a diffuser 48 was irradiated at surface 14a of the azo polymer layer 14. The speckle pattern of optical on-the-strength 2.2 W/cm2 was irradiated for 8 hours so that induction of the irregularity might fully be carried out to the azo polymer layer 14. The optical element (diffuser) by which the irregularity according to a speckle pattern was formed by this in surface 14a of the azo polymer layer 14 was obtained.
[0118] The result of having observed the concavo-convex pattern by which induction was carried out to drawing 24 at surface 14a of the azo polymer layer 14 by AFM (atomic force microscope) is shown. The maximum of the concavo-convex depth is about 1 micrometer, and the concavo-convex pitch became the configuration where during 100 micrometers [5 micrometers -] of abbreviation was distributed focusing on 50 micrometers. Thus, the speckle pattern was imprinted by the azo polymer layer 14 as irregularity.
[0119] Next, the diffusion property of this diffuser was evaluated. The diffusion property of the horizontal and the perpendicular direction of this optical element is shown in drawing 25 . As drawing 25 showed, the zero-order transmitted light did not have diffusion of the azo polymer layer 14, and it was non-isotropic diffusion. The diffusion property of this optical element is produced according to the refraction effectiveness by the irregularity formed in the front face.
[0120] Thus, in this example, the optical element (diffuser) which has a refraction function with the irregularity of the front face instead of refractive-index distribution is producible. Furthermore, the irregularity of this optical element can be imprinted mechanically, La Stampa can be produced, and it has the merit that the optical element equipped with the shape of same toothing using this La Stampa can be mass-produced.

[0121] (Example 4) By this example, in order to give the diffraction effect to the optical element of the refraction mold produced in the example 2, still more detailed irregularity is formed in the front face of the irregularity formed in the front face of an azo polymer layer, and the example which produced the optical element is explained.
[0122] Using 488nm of oscillation lines of an Ar ion laser as the light source, on the front face in which the irregularity of the azo polymer layer of the optical element produced in the example 2 was formed, it branches to two light waves and a laser beam is irradiated as body light and a reference beam. Polarization of body light and a reference beam was mutually made into the circular polarization of light of the circumference of reverse with the quarter-wave length plate. The surface relief hologram could be efficiently produced by this polarization arrangement, and 1 micrometer or less and the concavo-convex depth were able to form [the concavo-convex pitch] the detailed irregularity of 200nm or less in the front face of the irregularity formed in the azo polymer layer.
[0123] By adjusting the exposure energy of record light (body light and reference beam), it carried out as [diffract / primary plus light, primary minus light, and zero-order light / equally]. Thereby, as shown in drawing 9 (a), the diffused light of trifurcation is generated. The beam profile of the diffused light in this case is as being shown in drawing 9 (b).
[0124] Thus, in this example, the diffraction effect can be added by adding detailed irregularity to the front face of irregularity equipped with a refraction function. Moreover, in the optical element of this example, since both the refraction effectiveness with a lenticular lens and the diffraction effect by the detailed irregularity formed in the front face of an azo polymer layer are acquired, a complicated beam profile can be obtained according to an application.
[0125] In addition, the diffraction effect can be given by the same approach also about the optical element of the refraction mold produced in the example 3.
[0126] (Example 5) This example explains the example which produced the optical element suitable as an optical diffusion branching component used for an optical data bus and a signal processor which are indicated by JP,10-282371,A with reference to drawing 26 - drawing 28 .
[0127] As an azo polymer, the polyester (instantiation compound: azo polymer (6)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (6) is 33.1 degrees C, and is suitable for this invention.
[0128] First, the chloroform solution of an azo polymer (6) was applied to the concave convex of lenticular lens 12A with the spin coat. Thickness of the azo polymer layer 14 was set to 1 micrometer at this time. The azo polymer layer 14 was formed along with the irregularity of a lenticular lens 12A front face. As a lenticular lens, the lenticular lens of the quartz shown in drawing 4 (a) was used. As shown in drawing 4 (b), as for this lens, mesial magnitude full width diffuses 10 degrees of incident light. Moreover, the pitch of the irregularity of a lenticular lens is 166 micrometers, and the concavo-convex depth is 50 micrometers.
[0129] Next, in order to form in a Top Hat-like beam the diffusion angle of the lenticular lens of the quartz shown in drawing 4 (a), a surface relief hologram is produced using the optical system shown in drawing 27 . First, the space optical modulator 16 generated the light wave of the optical intensity distribution shown in drawing 26 (a). This light wave is beforehand designed so that the diffused light by lenticular lens 12A may be transformed into optical Top Hat-like intensity distribution.
[0130] While irradiating as a body light 30, condensing the generated light wave with a lens 70, the parallel reference beam 32 was irradiated by the beam splitter 72 at coincidence. The body light 30 and a reference beam 32 carried out incidence to surface 14a of the azo polymer layer 14 from surface 14b of the opposite side on the abbreviation same axle. The body light 30 and a reference beam 32 were mutually set as the circular polarization of light of the circumference of reverse. Moreover, exposure energy was adjusted so that the diffraction efficiency of a relief hologram might serve as 50% of abbreviation. A surface relief hologram is recorded by this and detailed irregularity is formed in surface 14a of the azo polymer layer 14. The concavo-convex pitch was 0.5-2.0 micrometers, and the concavo-convex depth was 200nm or less.
[0131] Next, incidence of the light was carried out from the surface 14a side of the azo polymer layer

14, and the hologram was reproduced. That is, among the light which carried out incidence, a half light was diffracted with the surface relief hologram, was refracted with the lenticular lens after that, and was diffused. Moreover, the light of the remaining one half which is not diffracted by the hologram was diffused with the lenticular lens as it was. As shown in drawing 28 , when these two diffused lights were put together, the Top Hat-like diffused light was able to be acquired as a result.
[0132] Thus, at this example, a half light is diffused by the dioptrics component, and the light of the remaining one half is generated with a diffracted-light study component so that the diffused light may be compensated. Therefore, it is suitable as an optical diffusion branching component for above-mentioned optical data buses.
[0133] (Example 6) By this example, a computer generated hologram is imprinted on the front face of an azo polymer layer, irregularity is formed in it, and the example which produced the optical element is explained.
[0134] First, a computer generated hologram is explained. Theoretically, if both complex amplitude of the light in the input screen of a computer generated hologram, i.e., a phase and the real amplitude, is decided, the complex amplitude in the output screen of a computer generated hologram can be decided. Analytical conversion relation can describe the relation of these two complex amplitude, and when both are seldom approaching, it has the relation of the Fourier transform. However, implementation of the component which modulates both a phase and the amplitude is difficult, and it is common that only the amplitude modulates only a phase. In the modulation of only a phase or the amplitude, there is no unique relation between a desired output and a computer generated hologram, and it cannot but depend on a retrieval-optimization technique.
[0135] Gerchberg-Saxton which performs the Fourier transform as the technique of optimization repeatedly until it converges -- there are an approach using the technique of neural networks, such as law and the SHUMIRETTEDDO annealing method, an approach using a genetic algorithm, etc. a pattern simple here -- Gerchberg-Saxton with comparatively quick convergence -- the computer generated hologram was computed using law.
[0136] Drawing 29 (b) is the optical intensity distribution in an output screen, and drawing 29 (a) is a computer generated hologram in the input screen for forming it. The computer generated hologram expresses phase distribution in an input screen, a white part corresponds to phase contrast pi, and the black part supports phase contrast-pi. In this example, an azo polymer is irradiated as a shade image as shows a phase contrast pattern to drawing 29 (b), and induction of the front face is carried out in a bright part. The phase of incident light is modulated according to this relief structure by which induction was carried out. Therefore, it is necessary to carry out induction of the irregularity equal to the phase contrast corresponding to a computer generated hologram.
[0137] Image formation of this computer generated hologram was reduced and carried out to surface 10a of the azo polymer support 10 according to the optical system shown in drawing 5 . As an azo polymer, the polyester (instantiation compound: azo polymer (7)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (7) is 38 degrees C, and is suitable for this invention. The maximum of the concavo-convex depth was about 1 micrometer, and the concavo-convex minimum pitch was about 1 micrometer.
[0138] Thus, the computer generated hologram was imprinted by azo polymer support as irregularity. The result of having observed the front face of azo polymer support by AFM is shown in drawing 32 . Moreover, incidence of the light is carried out to the obtained optical element, and the result of having evaluated the outgoing radiation light is shown in drawing 30 . In spite of having designed the computer generated hologram to four branching, outgoing radiation light became the light wave of 5 branching with the zero-order diffracted light from drawing 30 . Since induction of the irregularity equivalent to phase contrast pi was not carried out to the front face of azo polymer support, this originates in 100% of diffraction efficiency not having been acquired.
[0139] Next, in order to give a lens property to the obtained optical element, the computer generated hologram irradiated the light-and-darkness image corresponding to the configuration of the lenticular lens shown in drawing 6 on the front face of the azo polymer support imprinted as irregularity. At this

time, the optical system shown in drawing 5 was used. Induction of the irregularity was carried out to the azo polymer so that it might have an operation of a lenticular lens by this. The concavo-convex pitch was 10 micrometers. When incidence of the light was carried out to the obtained optical element, the diffused light of 5 branching of a mode profile shown in drawing 31 was able to be acquired.
[0140] (Example 7) This example explains the example which produced the metal master for reproducing an optical element using the optical element produced in the example 3 and the example 6.
[0141] Conductive processing is performed to the front face (correctly an azo polymer layer or the front face of azo polymer support) in which the irregularity of an optical element was formed by vacuum evaporationo or electroless deposition. Next, the metal master which is the metal mold of the negative of an optical element is producible with nickel electrocasting etc. If the metal master by which irregularity was imprinted by the precision can be obtained, the rest can obtain a duplicate object easily by producing La Stampa using this metal master, and imprinting a concavo-convex pattern by thermocompression bonding, injection-molding processing, etc. into resin ingredients, such as an acrylic, Pori Karr Nate, and polyester, using this La Stampa.
[0142] Drawing 33 (a) and (b) are the AFM images on the front face of a metal master produced using the optical element obtained in the example 3. Irregularity performed electroless deposition to the front face of the azo polymer layer by which induction was carried out, and produced after that the metal master which is metal mold by nickel electrocasting. By comparing drawing 33 (a), and (b) and drawing 24 shows that the shape of surface type of an azo polymer layer is correctly imprinted by the metal master.
[0143] Drawing 34 (a) and (c) are the AFM images of the azo polymer layer front face of the optical element obtained in the example 6, and drawing 34 (b) and (d) are the AFM images on the front face of a metal master produced using this. Irregularity gave golden vacuum evaporationo to the front face of the azo polymer layer by which induction was carried out, and produced the metal master by nickel electrocasting after that. Drawing 34 (a) - (d) shows that the shape of surface type of an azo polymer layer is correctly imprinted by the metal master.
[0144] Therefore, even if it is the optical element equipped with complicated irregularity by manufacturing an optical element by the above-mentioned approach using this metal master, that duplicate can be mass-produced to simple and low cost.
[0145] (Example 8) This example explains the example which imprinted the speckle pattern from a diffuser on the front face of the azo polymer layer formed in the front face of a lenticular lens, formed irregularity in it, and produced the optical element.
[0146] As an azo polymer, the polyester (instantiation compound: azo polymer (4)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (4) is 48.5 degrees C, and is suitable for this invention.
[0147] First, the chloroform solution of an azo polymer (4) was applied to the concave convex of lenticular lens 12A with the spin coat, and the azo polymer layer 14 with a thickness of 3 micrometers was formed. The azo polymer layer 14 was formed along with the irregularity of a lenticular lens 12A front face. As a lenticular lens, the lenticular lens of the quartz shown in drawing 4 (a) was used. As shown in drawing 4 (b), as for this lens, mesial magnitude full width diffuses 10 degrees of incident light. Moreover, the pitch of the irregularity of a lenticular lens is 166 micrometers.
[0148] Next, the speckle pattern from a diffuser is imprinted to surface 14a of the azo polymer layer 14 using the speckle imprint optical system shown in drawing 13 . That is, incidence of the laser beam 42 from the light source 40 was carried out to the diffuser 48 as the circular polarization of light 46 with the quarter-wave length plate 44, using 488nm of oscillation lines of an Ar ion laser as the light source. The non-isotropic-diffusion object which generates the diffused light of an ellipse as a diffuser 48 was used. The record medium equipped with the azo polymer layer 14 behind [5mm] the diffuser 48 has been arranged, and the diffused light 50 by which outgoing radiation is carried out behind a diffuser 48 was irradiated at surface 14a of the azo polymer layer 14. The speckle pattern of optical on-the-strength 2.2 W/cm2 was irradiated for 8 hours so that induction of the irregularity might fully be carried out to surface 14a of the azo polymer layer 14. Thereby, as shown in drawing 14 , the optical element

(diffuser) by which the irregularity 52 according to a speckle pattern was formed in the azo polymer layer 14 was obtained. In addition, the maximum of the concavo-convex depth of irregularity 52 is about 1 micrometer, and the concavo-convex pitch became the configuration where it was distributed over the range of 100 micrometers [5 micrometers -] of abbreviation focusing on 50 micrometers.

[0149] The diffusion property of the horizontal and the perpendicular direction of this optical element is shown in drawing 15 . A continuous line shows the diffusion property after a speckle pattern imprint, and a dotted line shows the diffusion property before a speckle pattern imprint. The direction of the optical element which formed the irregularity 52 according to a speckle pattern in the azo polymer layer 14 is excellent in the diffusion property so that drawing 15 may show. That is, the diffusion property improved according to the-like secondary refraction effectiveness by the irregularity 52 formed in the front face of the azo polymer layer 14.

[0150] Moreover, in this example, not refractive-index distribution but the diffusion component by surface irregularity is producible. Therefore, the irregularity on this front face of an optical element is imprinted mechanically, the master diffuser of a negative is produced, and there is a merit that a duplicate object can be mass-produced based on this master diffuser.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] Especially this invention is equipped with the macromolecule layer which has an azobenzene frame about the manufacture approach of the manufacture approach of an optical element and an optical element, an optical element duplicate object, and an optical element duplicate object, and relates to the manufacture approach of the optical element which has either [at least] a refraction function or a diffraction function, the manufacture approach of the optical element, the duplicate object of the optical element, and an optical element duplicate object.
[0002]
[Description of the Prior Art] Conventionally, in the field of an optical instrument, the optical element (dioptrics component) using optical refraction, such as a convex lens, a concave lens, and prism, has been used widely. Recently, production of a micro-lens array, a lenticular lens, etc. is also attained by development of ultra-fine processing technology, and the dioptrics component is used in various applications from lighting to optical communication.
[0003] For example, the signal processor using the optical data bus equipped with the lenticular lens and this optical data bus is indicated by JP,10-282371,A. This optical data bus 10 forms two or more cylindrical sides (lenticular lens) 12 arranged along with edge 11a which makes the optical data bus 10 interior diffuse the signal light 15 which carried out incidence to one edge 11a of the signal light incidence section 11, as shown in drawing 35 (a) and (b). Since the cylindrical side 12 diffuses the signal light 15 by which incidence was carried out to the optical data bus 10 over the whole surface of edge 14a by the side of the signal light outgoing radiation section 14 with the diffusion means which comes to carry out two or more arrays, the signal light left besides the optical transmission layer 13 among signal light is stopped to the minimum. The transmission efficiency of the signal light 15 becomes high by this, and dispersion in the amount of outgoing radiation in edge 14a by the side of the signal light outgoing radiation section 14 decreases. For this reason, low consumption electrical quantity-ization can be attained in the signal processor using the optical data bus 10.
[0004]
[Problem(s) to be Solved by the Invention] However, dioptrics components, such as a lens, are equipped only with the function of comparatively simple condensing or optical diffusion. For example, in an above-mentioned optical data bus, signal light is only diffused with the lenticular lens. On the other hand, when Holographic Optical Element (HOE) which is a diffracted-light study component using the diffracted-light study component which used the diffraction of light instead of and a hologram is used, a complicated light wave can be generated. [the dioptrics component]
[0005] For example, in the above-mentioned optical data bus 10, as shown in drawing 35 (c) The signal light 15 by which incidence was carried out to it in the optical data bus 10 when the diffusion plate 20 had been arranged to one edge 11a of the signal light incidence section 11 as a diffracted-light study component instead of the lenticular lens It diffracts with the diffusion plate 20, and it is spread, while branching so that it may condense to the predetermined output port (for example, output ports 14b and

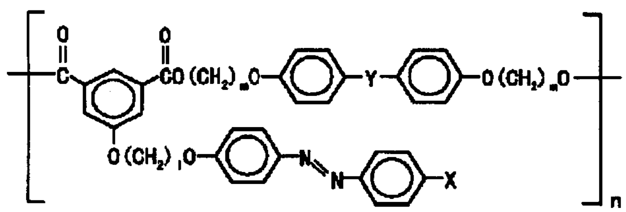
14c) established in edge 14a by the side of the signal light outgoing radiation section 14.
[0006] According to the diffracted-light study component this passage, an incident wave side is convertible for the wave front designed to arbitration. Moreover, the diffracted-light study component had the variance contrary to a refraction mold lens, and since it does not have thickness substantially, it is equipped with the advantage which is not in a dioptrics component -- optical system becomes compact. On the other hand, in order [the] to use the diffraction of light, there is a trouble of diffraction efficiency essentially falling compared with a dioptrics component according to generating of zero-order light with large wavelength dispersion with large constraint of alignment.
[0007] moreover, as the production approach of a diffracted-light study component of having used the hologram Photofabrication of surfaces for holograms, As indicated by Sukant Tripathy, Dong-Yu Kim, Lian Li, and Jayant Kumar, and CHEMTECH MAY (1998) pp.34-40. The approach of forming in a medium front face the surface relief hologram with which induction of the detailed irregularity was carried out by recording a hologram on this record medium is learned using the record medium which consists of a macromolecule (azo polymer) which has an azobenzene frame.
[0008] Using the laser light source of the wavelength which has sensibility in an azo polymer, two light waves are made to interfere and, specifically, the surface relief hologram of a submicron pitch is formed on the surface of a record medium. Although the HOE production process in which the usual semi-conductor process is used needs many processes in order to repeat a pattern design, exposure, and development two or more times, by the above-mentioned approach, it can skip many processes and can reduce a manufacturing cost sharply. Moreover, since the relief depth of the surface relief hologram formed increases in proportion to exposure energy, production of an ideal diffracted-light study component from which irregularity changed gently is possible for it.
[0009] However, the relief depth obtained by the above-mentioned approach is about several 100nm, when forming a surface relief hologram and using it as a diffracted-light study component, sufficient relief depth is not obtained, but the zero-order light which is not diffracted occurs and the practical problem that diffraction efficiency falls usually generates it.
[0010] Although there is an advantage that the degree of freedom of a design is large in the diffracted-light study component containing HOE as stated above, there are problems, like in order to use the diffraction of light, constraint of alignment is essentially large, and wavelength dispersion is large. On the other hand, although the degree of freedom of a design is small, dioptrics components, such as a lens, have little constraint of alignment, wavelength dispersion is small for them, and the problem by zero-order light has the advantage (robustness of a dioptrics component) of not generating in them.
[0011] This invention is made in view of the above-mentioned trouble, and the 1st purpose of this invention is to offer the optical element which can acquire the outstanding refraction effectiveness or the outstanding diffraction effect with the irregularity formed in the front face. The 2nd purpose of this invention is to offer the optical element which can obtain the light beam of the configuration of arbitration according to the refraction effectiveness and the diffraction effect. It is to offer the optical element which can acquire the outstanding refraction effectiveness and/or the outstanding diffraction effect while the degree of freedom of the purpose [3rd] of this invention of a design improves by forming the irregularity (relief structure) of sufficient depth for a front face.
[0012] The 4th purpose of this invention is by irradiating the optical pattern of arbitration and carrying out induction of the irregularity of a request configuration to a front face to offer the manufacture approach of an optical element that the optical element by which irregularity was formed in the front face can be manufactured simple and cheaply. Using the optical element by which irregularity was formed in the front face, the 5th purpose of this invention can reproduce easily the optical element of the shape of same surface type, and is to offer the optical element duplicate object obtained by the manufacture approach and approach of the suitable optical element duplicate object for mass production method.
[0013]
[Means for Solving the Problem] In order to attain the 1st above-mentioned purpose, an optical element according to claim 1 is equipped with the macromolecule layer which has an azobenzene frame, and is

characterized by forming in the front face of this macromolecule layer the irregularity which has a refraction function. In this optical element, the refraction effectiveness can be acquired with the irregularity formed in the front face of a macromolecule layer. Moreover, although diffraction efficiency falls if sufficient concavo-convex depth is not obtained, in this optical element, the outstanding refraction effectiveness can be acquired by optimizing concavo-convex spacing irrespective of the concavo-convex depth.
[0014] In order to attain the 1st above-mentioned purpose, an optical element according to claim 2 is equipped with the macromolecule layer which has an azobenzene frame, and is characterized by forming in the front face of this macromolecule layer irregularity with a depth of 1 micrometers or more which has a diffraction function. The outstanding diffraction effect can be acquired in this optical element, without diffraction efficiency falling with irregularity with a depth of 1 micrometers or more formed in the front face of a macromolecule layer.
[0015] In order to attain the 1st or 2nd above-mentioned purpose, an optical element according to claim 3 is equipped with the macromolecule layer which has an azobenzene frame, and it is characterized by forming in the front face of this 1st irregularity the 2nd irregularity which has a refraction function or a diffraction function while the 1st irregularity which has a refraction function is formed in the front face of this macromolecule layer. In this optical element, while the refraction effectiveness is acquired with the 1st irregularity formed in the front face of a macromolecule layer, the refraction effectiveness or the diffraction effect can be acquired with the 2nd irregularity formed in the front face of the 1st irregularity.

[0016] That is, in addition to the refraction effectiveness by the 1st irregularity, the outstanding refraction effectiveness can be acquired by acquiring the refraction effectiveness by the 2nd irregularity. Moreover, when acquiring the diffraction effect by the 2nd irregularity in addition to the refraction effectiveness by the 1st irregularity, the light beam of the configuration of arbitration can be obtained.
[0017] In order to attain the 1st or 2nd above-mentioned purpose, an optical element according to claim 4 is equipped with a dioptrics component and the macromolecule layer which has the azobenzene frame formed in the front face of this dioptrics component, and is characterized by forming in the front face of this macromolecule layer the irregularity which has either [at least] a refraction function or a diffraction function. In this optical element, while the refraction effectiveness is acquired by the dioptrics component, either [at least] the refraction effectiveness or the diffraction effect can be acquired with the irregularity formed in the front face of a macromolecule layer.
[0018] That is, in addition to the refraction effectiveness by the dioptrics component, the outstanding refraction effectiveness can be acquired by acquiring the refraction effectiveness by irregularity. Moreover, when acquiring the diffraction effect by irregularity in addition to the refraction effectiveness by the dioptrics component, the light beam of the configuration of arbitration can be obtained.
[0019] In order to attain the 1st or 2nd above-mentioned purpose, an optical element according to claim 5 is equipped with the macromolecule layer which has an azobenzene frame, and it is characterized by forming the 2nd irregularity in the front face of this 1st irregularity at spacing narrower than this 1st irregularity while the 1st irregularity which has a refraction function is formed in the front face of this macromolecule layer. In this optical element, while the refraction effectiveness is acquired with the 1st irregularity formed in the front face of a macromolecule layer, according to the configuration of the 2nd irregularity formed in the front face of this 1st irregularity, either [at least] the refraction effectiveness or the diffraction effect can be acquired.
[0020] In order to attain the 1st or 2nd above-mentioned purpose, an optical element according to claim 6 is equipped with the dioptrics component equipped with the 1st irregularity which has a refraction function, and the macromolecule layer which has an azobenzene frame on the front face of this 1st irregularity, and is characterized by forming the 2nd irregularity in the front face of this macromolecule layer at spacing narrower than said 1st irregularity. In this optical element, while the refraction effectiveness is acquired with the 1st irregularity in the front face of a dioptrics component, according to the configuration of the 2nd irregularity formed in the front face of this 1st irregularity, either [at least] the refraction effectiveness or the diffraction effect can be acquired.

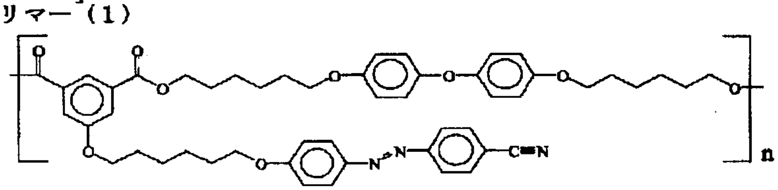
[0021] In the above-mentioned optical element, it is desirable to be formed at spacing whose irregularity which has a refraction function is 5-100 micrometers, and it is desirable to be formed at spacing whose irregularity which has a diffraction function is 0.2-5 micrometers.
[0022] As for the glass transition point of a macromolecule, in the above-mentioned optical element, it is more desirable than a room temperature that it is either of the range of 20 degrees C - 50 degrees C an elevated temperature and near the room temperature.
[0023] In order to attain the 3rd above-mentioned purpose, an optical element according to claim 12 is characterized by forming the irregularity to which it has the macromolecule layer which has an azobenzene frame, and the glass transition point of this macromolecule is an elevated temperature from a room temperature, and has either [at least] a refraction function or a diffraction function on the front face of said macromolecule layer. From a room temperature, when it irradiates light when the glass transition point of a macromolecule is an elevated temperature, and it carries out induction of the irregularity, while it can carry out induction of the irregularity of sufficient depth, it can maintain the irregularity by which induction was carried out to stability. Consequently, easy and the refraction effectiveness which was excellent while it could form in stability and the degree of freedom of a design improved, and/or the outstanding diffraction effect can be acquired for the irregularity of sufficient depth on the surface of an optical element.
[0024] Moreover, in order to attain the 3rd above-mentioned purpose, it has the macromolecule layer which has an azobenzene frame, the glass transition point of this macromolecule is near the room temperature, and an optical element according to claim 13 is characterized by forming in the front face of said macromolecule layer the irregularity which has either [at least] a refraction function or a diffraction function. When irradiating light when the glass transition point of a macromolecule is near the room temperature, and carrying out induction of the irregularity, the induction of the irregularity of sufficient depth can be carried out. Consequently, while the irregularity of sufficient depth can be easily formed on the surface of an optical element and the degree of freedom of a design improves, the outstanding refraction effectiveness and/or the outstanding diffraction effect can be acquired.
[0025] Moreover, in order to attain the 3rd above-mentioned purpose, an optical element according to claim 14 is equipped with the macromolecule layer which has an azobenzene frame, is range whose glass transition point of this macromolecule is 20 degrees C - 50 degrees C, and is characterized by forming in the front face of said macromolecule layer the irregularity which has either [at least] a refraction function or a diffraction function. When irradiating light when the glass transition point of a macromolecule is the range which is 20 degrees C - 50 degrees C, and carrying out induction of the irregularity, while being able to carry out the induction of the irregularity of sufficient depth, the irregularity by which induction was carried out is maintainable to stability. Consequently, easy and the refraction effectiveness which was excellent while it could form in stability and the degree of freedom of a design improved, and/or the outstanding diffraction effect can be acquired for the irregularity of sufficient depth on the surface of an optical element.
[0026] In an optical element according to claim 12 to 14, the irregularity concerning the part which has a refraction function among the irregularity formed in the front face of a macromolecule layer can be formed at intervals of 5-100 micrometers. Moreover, as for the irregularity concerning the part which can form the irregularity concerning the part which has a diffraction function among the irregularity formed in the front face of a macromolecule layer at intervals of 0.2-5 micrometers, and has a diffraction function, it is desirable to be formed in a depth of 1 micrometers or more. Furthermore, it can have the 1st irregularity which is formed in the front face of a macromolecule layer and has a refraction function as irregularity formed in the front face of a macromolecule layer, and the 2nd irregularity which is formed in the front face of this 1st irregularity, and has a refraction function or a diffraction function. Moreover, the macromolecule layer may be formed in the front face of a dioptrics component.
[0027] In the above-mentioned optical element, the hologram may be recorded on the interior of a macromolecule layer. In this case, a diffraction function can be obtained by the hologram recorded on the interior.
[0028] In order to enable formation of deeper irregularity, as for the thickness of a macromolecule layer,

it is desirable to be referred to as 1-10 micrometers. Moreover, as for a giant molecule, what has an azobenzene frame in a side chain is desirable, and what contains an aromatic hydrocarbon radical in a principal chain is more desirable. Also in these macromolecules, especially the polyester expressed with the following general formula (1) is desirable.
[0029]
[Formula 2]
一般式（1）



[0030] (Among a formula, X shows a cyano group, a methyl group, a methoxy group, or a nitro group, and Y shows the divalent connection radical by ether linkage, ketone association, or sulfone association.) l and m show the integer of 2-18, and n shows the integer of 5-500. In order to attain the 4th above-mentioned purpose, invention according to claim 25 is the manufacture approach of an optical element of manufacturing the optical element of this invention, and is characterized by irradiating the light which has predetermined intensity distribution, forming the irregularity according to these intensity distribution in the front face of a macromolecule layer established in the optical element, and manufacturing an optical element. In this case, it is desirable that the light to irradiate is the circular polarization of light. Moreover, predetermined intensity distribution can be made into the intensity distribution corresponding to a computer generated hologram or kino form, and the intensity distribution corresponding to the speckle pattern obtained from the diffuser.
[0031] By this manufacture approach, by irradiating the optical pattern of arbitration, the light which has the intensity distribution corresponding to a computer generated hologram or kino form, the light which has the intensity distribution corresponding to the speckle pattern obtained from the diffuser can form the irregularity of a request configuration in the front face of a macromolecule layer, and can manufacture simple and cheaply the optical element by which irregularity was formed in the front face of a macromolecule layer.
[0032] Moreover, in order to attain the 4th above-mentioned purpose, invention according to claim 29 is the manufacture approach of an optical element of manufacturing the optical element of this invention, and is characterized by irradiating body light and a reference beam on the front face of a macromolecule layer established in the optical element, forming the irregularity according to the intensity distribution by the interference light of this body light and a reference beam, and manufacturing an optical element. In this case, as for body light and a reference beam, it is desirable that it is the circular polarization of light of the circumference of reverse mutually.
[0033] By this manufacture approach, by irradiating the optical pattern of arbitration, the interference fringe of light etc. can form the irregularity of a request configuration in the front face of a macromolecule layer, and can manufacture simple and cheaply the optical element by which irregularity was formed in the front face of a macromolecule layer, for example.
[0034] In order to attain the 5th above-mentioned purpose, the manufacture approach of an optical element duplicate object according to claim 31 Are the manufacture approach of an optical element duplicate object of manufacturing the duplicate object of the optical element of this invention, produce La Stampa for imprinting this irregularity using the irregularity formed in the front face of said optical element, and with the thermocompression bonding or injection molding using this La Stampa It is characterized by forming said irregularity and the irregularity of the same configuration in the front face of a resin ingredient, and manufacturing the duplicate object of said optical element.

[0035] Moreover, in order to attain the 5th above-mentioned purpose, an optical element duplicate object according to claim 32 is characterized by imprinting the irregularity formed in the front face of the optical element of this invention.
[0036] By the manufacture approach of the above-mentioned optical element duplicate object, La Stampa for imprinting this irregularity is producible using the irregularity formed in the front face of the optical element of this invention, such as performing mastering using the optical element of this invention, producing a metal master for example, and producing La Stampa based on this metal master. And by the approach suitable for mass production method, such as thermocompression bonding or injection molding using this La Stampa, the irregularity of the same configuration as the irregularity formed in the front face of a resin ingredient on the surface of the optical element can be formed, and the optical element of the shape of same surface type can be reproduced easily. For this reason, the optical element of the shape of complicated surface type can also be mass-produced easily. Moreover, the obtained optical element duplicate object demonstrates the outstanding refraction effectiveness and/or the outstanding diffraction effect like the optical element of this invention.
[0037]
[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained with reference to a drawing.
[Ingredient of a polymer carrier or a giant-molecule layer] The polymeric materials used for the optical element of this invention are giant molecules (an "azo polymer" is called hereafter) which have an azobenzene frame. This azobenzene frame shows the photoisomerization cycle of a transformer-cis--transformer.
[0038] this invention -- setting -- the inside of these azo polymer -- a glass transition point Tg -- a near room temperature -- a hot azo polymer is somewhat more desirable especially preferably than a room temperature. The former, Photofabrication of surfaces for holograms, As indicated by Sukant Tripathy, Dong-Yu Kim, LianLi, and Jayant Kumar, and CHEMTECH MAY (1998) pp.34-40. Although the azo polymer 100 degrees C or more was used for surface relief formation, a glass transition point Tg this invention person etc. is that a glass transition point Tg uses the azo polymer near the room temperature for a record medium, and, as for deep relief structure, easy and being obtained by stability raised sharply the degree of freedom of a design of a header and an optical element.
[0039] Moreover, the macromolecule which contains an azobenzene frame in a side chain from a viewpoint of the molecular structure is desirable, and the macromolecule which contains an aromatic hydrocarbon radical in a principal chain is more desirable. Also in these, especially the polyester expressed with the above-mentioned general formula (1) is desirable.
[0040] The example of the azo polymer which can be used by this invention is shown below.
[0041]
[Formula 3]
アゾポリマー (1)



[0042] The polyester (azo polymer (1)) which has a cyano azobenzene in the above-mentioned side chain is M.Sato's and others "Synthesis and properties of polyesters having cyanoazobenzene units in the side chain", and Macromol.Rapid. Commun. It is reported to 15 and 21-29 (1994), and can compound by the approach indicated by this reference. Next, the synthesis procedure of this azo polymer (1) is explained.
[0043] (Composition of a 4-hydroxy-4'-cyano azobenzene) NaNO2 water solution (NaNO2150g, 750ml of pure water) was dropped, stirring two mols (236.3g) of 4-amino benzonitriles, 600ml (12Ns) of HCl (s), and 600ml of pure water in an ice bath (step 1). Two mols (191.8g) of phenols and two mol (112.3g)

of KOH(s) are quickly dissolved in about 2l. pure water, and the product of step 1 was dropped and was made to react. After reaction termination, after ****(ing) a product by suction filtration, reduced pressure drying was washed and carried out with pure water. The obtained product was made to recrystallize with a methanol and the crystal of 1.3 mols of 4-hydroxy-4'-cyano azobenzenes (292.3g, 65.5% of yield) was obtained.

[0044] (Composition of a 4-(6-BUROMO hexyloxy)-4'-cyano azobenzene) 0.2 mols (44.6g) of 4-hydroxy-4'-cyano azobenzenes, 1, two mols (488.1g) of 6-dibromo hexanes, 31.45 mols (200.4g) of K2COs, and 800ml of acetones are put into a 2l. three-neck flask, and it flowed back for 20 hours and was made to react using a water bus. After cooling to a room temperature, a by-product and superfluous K2CO3 were filtered and removed. After condensing the obtained filtrate to about about 1 / 2 using a rotary evaporator, it was left in the freezer and it was crystallized. After ****(ing) the depositing crystal by suction filtration, reduced pressure drying was washed and carried out by n-hexane (0.117 mols (45.3g, 58.6% of yield)). Furthermore, the obtained rough crystal was made to recrystallize in ethanol, and 0.094 mols (36.3g, 47.0% of yield) of 4-(6-BUROMO hexyloxy)-4'-cyano azobenzenes were obtained.

[0045] (Composition of 5-hydroxy isophthalic acid diethyl ester) One mol (182.4g) of 5-hydroxy isophthalic acid, 1500ml of ethanol, and 10ml of concentrated sulfuric acid are put into a 2l. three-neck flask, and it flowed back for 24 hours and was made to react using a water bus. After condensing reaction mixture using the rotary evaporator and filling NaHCO3 water solution with concentration liquid, reduced pressure drying of the product was ****(ed) and carried out, and 0.096 mols (228.8g, 96.0% of yield) of 5-hydroxy isophthalic acid diethyl ester were obtained. Furthermore, the obtained product was made to recrystallize in ethanol and reduced pressure drying was carried out under heating (50-60 degrees C).

[0046] (Side-chain section monomer: 5 -(4-cyanobenzene azo phenoxy hexyloxy)- Composition of isophthalic acid ethyl ester) 0.08 mols (30.9g) of 4-(6-BUROMO hexyloxy)-4'-cyano azobenzenes, 0.08 mols of 5-hydroxy isophthalic acid diethyl ester, 30.12 mols (16.58g) of K2COs, and 400ml of acetones are put into a 1l. three-neck flask, and it flowed back for 24 hours and was made to react using a water bus. About 4l. pure water was filled with reaction mixture after radiationnal cooling, and reduced pressure drying of the precipitate was filtered, taken out and carried out (0.071 mols (38.8g, 89.2% of yield)). 5 which is made to recrystallize with an acetone after that and becomes a side-chain section monomer -(4-cyanobenzene azo phenoxy hexyloxy)- The crystal of 0.058 mols of isophthalic acid ethyl ester (31.4g, 72.2% of yield) was obtained. The melting point of the obtained crystal is 99.0 degrees C, and had the absorption peak in 364.2nm.

[0047] A FTIR spectrum and 1 H-NMR performed identification of a side-chain section monomer. The measurement result of FTIR is shown below.

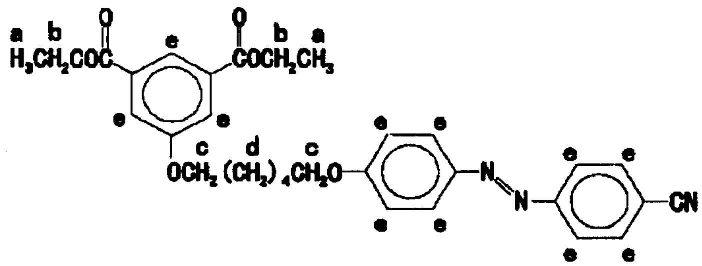
FTIR(KBr): 2947.7cm-1 (CH telescopic motion), 2227.4cm-1(CN)1713.4cm-1 (ester C=O), 1599.7cm-1 (C=C), 1580cm-1 (N=N), 1244.8cm-1 (C-O-C)

Moreover, the result of 1 H-NMR analysis of a spectrum is shown in the following table 1.

[0048]

[Table 1]

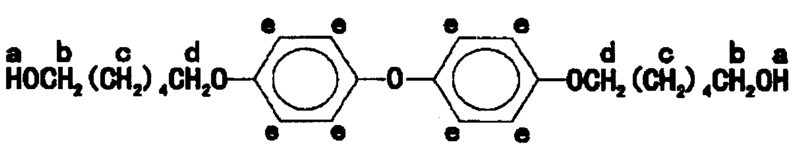
側鎖部モノマー^{1}H NMRスペクトルの化学シフト ($CDCl_3$)



diethyl-5-(4-cyanobenzeneazophenoxyhexyloxy) isophthalate
(543. 61)

水素の位置	a	b	c	d	e		
δ (ppm)	1. 40 (6H)	4. 39 (4H)	4. 07 (4H)	1. 58～1. 88 (8H)	7. 00～7. 03 (2H)	7. 73～7. 79 (5H)	7. 91～7. 94 (4H)

[0049] (Principal-chain section monomer: Composition of the bis(4-hydronalium hexyloxy phenyl) ether) 0.3 mols (60.66g) of 4 and 4'-dihydroxy diphenyl ether, 0.66 mols (90.16g) of 6-chloro-1-hexanols, 30.7 mols (97g) of K2COs, and 250ml of N.N-dimethylformamide were mixed, and it heated at 160 degrees C using the oil bath, and was made to react for 24 hours. Then, the water containing a small amount of hydrochloric acid was filled with reaction mixture, the product was ****(ed) by suction filtration, carried out reduced pressure drying, and the bis(4-hydronalium hexyloxy phenyl) ether was obtained. Furthermore, the obtained product was made to recrystallize from a water-N.N-dimethylformamide system partially aromatic solvent, and the crystal of the bis(4-hydronalium hexyloxy phenyl) ether was obtained almost quantitatively. The melting point of the obtained crystal was 119 degrees C.
[0050] A FTIR spectrum and 1 H-NMR performed identification of a principal chain section monomer. The measurement result of FTIR is shown below.
FTIR(KBr, JASCO FT/IR -230): 3312.1cm-1(OH)2936.1cm-1 (CH telescopic motion), 1505.2cm-1 (aromatic series), 1241.9cm-1 (C-O-C)
Moreover, the result of 1 H-NMR analysis of a spectrum is shown in the following table 2.
[0051]
[Table 2]
主鎖部モノマー^{1}H NMRスペクトルの化学シフト ($CDCl_3$)

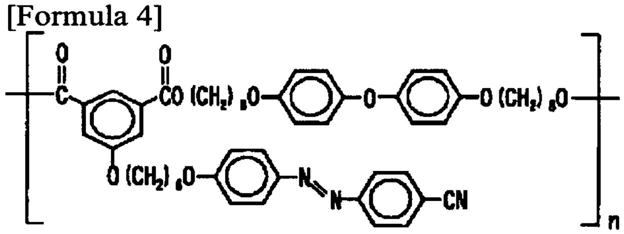


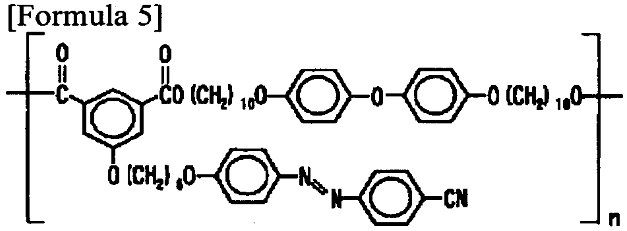
bis(4-hydrohexyloxyphenyl) ether
(402. 52)

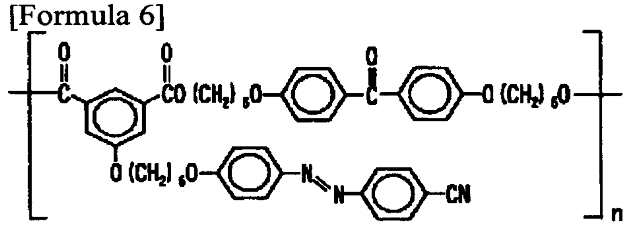
水素の位置	a	b	c	d	E
δ (ppm)	1. 30 (2H)	3. 67 (4H)	1. 44～1. 82 (16H)	3. 93 (4H)	6. 82～6. 92 (8H)

[0052] (Melt polycondensation of the polyester which has an azobenzene in a side chain) Side-chain

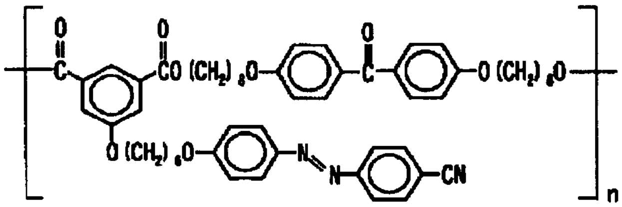
section monomer: 5 -(4-cyanobenzene azo phenoxy HEKISHINOKISHI)- 0.01 mols (5.4361g) of isophthalic acid ethyl ester, 0.01 mols (4.0253g) of principal chain section monomer:bis(4-hydronalium hexyloxy phenyl) ether, and 0.1g of acetic-anhydride zinc were put into the 300ml three-neck flask, and it was made to react under nitrogen-gas-atmosphere mind according to the following step of 1-4.
1) Decompressed to reaction 210Torr (1.33x103Pa) at about 160 degrees C for 2 hours, chloroform was made to dissolve after the 2-hour reaction above-mentioned reaction termination and reaction mixture in 180 degrees C and 2 - 5Torr (0.27x103 to 0.67x103Pa) over reaction 3 30 minutes for 20 minutes by the temperature up and reduced pressure 4 180 degree C, and 2 - 5Torr (0.27x103 to 0.67x103Pa), and it poured into the methanol. Precipitate was filtered and taken out, after carrying out heating washing with pure water, with the methanol, heating washing was carried out, reduced pressure drying was carried out, and the polyester which has a cyano azobenzene in a side chain was obtained almost quantitatively.
[0053] The DSC (differential scanning calorimeter) curve of the azo polymer (1) compounded by the above-mentioned approach to drawing 1 is shown. Glass transition temperature Tg was 38 degrees C, and the melting point Tm was 65 degrees C. Moreover, according to polarization microscope observation, the liquid crystal phase was a macromolecule which does not exist but has a birefringence in a solid state.
[0054] Next, the record medium which has the macromolecule layer which consists of an azo polymer (1) on a substrate was created. First, the azo polymer (1) compounded by the above-mentioned approach was melted by the concentration of 0.8g/ml with chloroform, and carried out the spin coat on the washed glass substrate (1000rpm, 20 seconds). After making it dry, it heated and quenched to the temperature which becomes an isotropic phase, and the macromolecule layer which consists of an azo polymer (1) was formed. It checked that the macromolecule layer formed of polarization microscope observation was the isotropic amorphous film. Moreover, it was 1.5 micrometers when thickness was measured using the sensing-pin-type surface roughness meter.
[0055] The surface relief hologram was formed using this record medium, and the relation between the concavo-convex depth (relief depth) and exposure energy was investigated. If in charge of formation of a surface relief hologram, while branching to two light waves and making this into body light and a reference beam using the 515nm oscillation line of an Ar ion laser, each polarization was mutually made into the circular polarization of light of the circumference of reverse. Exposure reinforcement was made into 0.5 W/cm2. The crossed axes angle of two light waves was adjusted so that spacing of the grating formed might become two kinds which are 1 micrometer and 10 micrometers, and the situation of relief development was investigated. A result is shown in drawing 2 .
[0056] When exposure energy increased so that drawing 2 might show, the relief depth also increased. Moreover, the irregularity of the depth exceeding 1 micrometer has been formed in the grating whose spacing is 10 micrometers. Moreover, the grating of 1-micrometer spacing has formed irregularity with a smaller than it depth of about 0.25 micrometers.
[0057] Thus, in the record medium using an azo polymer (1), induction of the relief deeper than before can be carried out. Since Tg of an azo polymer is near the room temperature, this is conjectured to be for the molecule migration by optical exposure to take place easily. If the azo polymer of Tg lower than a room temperature is used, although induction of the deep relief will be carried out on the other hand at the time of an optical exposure, the configuration is not maintained after optical cutoff and the optical element with irregularity deep as a result cannot be realized. Therefore, deep relief structures are easy and the point acquired by stability, and Tg somewhat higher than a room temperature and the azo polymer which shows Tg of the range of 20 degrees C - 50 degrees C preferably are suitable for this invention as described above.
[0058] Next, when changed various thickness of the macromolecule layer which consists of an azo polymer (1), two or more record media were produced, the surface relief hologram was formed about each record medium and the relation between the relief depth and exposure energy was investigated, it was checked that induction of the irregularity of the magnitude same in the range whose thickness of an azo polymer is 1 micrometer - 10 micrometers as the case where it is shown in drawing 2 is carried out.
[0059] Although two or more reports of the example by which induction of the irregularity was carried

out to the azo polymer layer of 100nm of thickness numbers by the about dozens to 100-micrometer thin film are carried out conventionally, the example which carried out induction of the deep relief structure to the thick azo polymer layer exceeding several micrometers is not reported. In this invention, also when thickness of an azo polymer layer was thickened with 1micro - 10 micrometers, it was shown clearly that the induction of the irregularity of several micrometers can be effectively carried out from hundreds of nm. That is, it found out that very big surface relief structure was generable by using for a record medium the azo polymer which has suitable Tg, making the thickness comparatively thick, and recording a hologram as described above. And the degree of freedom of a design of an optical element was able to be sharply raised by applying this to an optical element.
[0060] The example (a chemical structure type and its Tg) of other azo polymers which can be used by this invention is shown below. These azo polymers are compoundable by the same approach as an azo polymer (1).
[0061]
[Formula 4]

Tg=26.8℃, Tm=56.4℃
アゾポリマー(2)

[0062]
[Formula 5]

Tg=23.9℃, Tm=62.7℃
アゾポリマー(3)

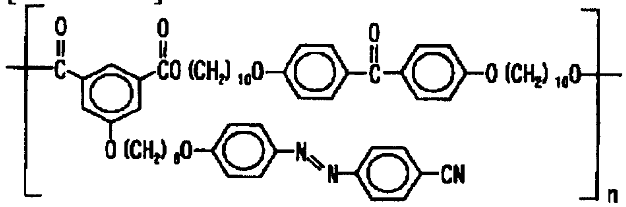
[0063]
[Formula 6]

Tg=48.5℃, Tm=82.2℃
アゾポリマー(4)

[0064]
[Formula 7]



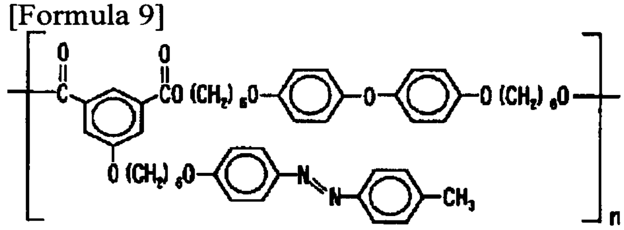
Tg=37.8℃, Tm=70.2℃
アゾポリマー(5)

[0065]
[Formula 8]



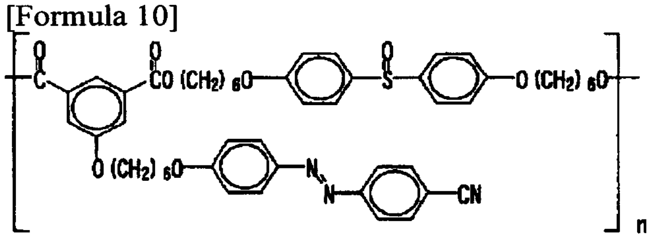
Tg=33.1℃, Tm=68.5℃
アゾポリマー(6)

[0066]
[Formula 9]



Tg=38.0℃
アゾポリマー(7)

[0067]
[Formula 10]



アゾポリマー(8)

[0068] As above-mentioned, Tg of the illustrated azo polymer is within the limits of 20 to 50 degrees C, and it was checked also in the relief formation experiment that the induction of the deep irregularity can be carried out like an azo polymer (1).
[0069] [Gestalt of an optical element] As shown in drawing 3 (a), the optical element of this invention can be constituted so that it may have the azo polymer support 10. In addition, azo polymer support consists of only azo polymer layers. The irregularity of the predetermined configuration which has either [at least] a refraction function or a diffraction function is formed in surface 10a of the azo polymer support 10. This irregularity can be formed by irradiating the light of the predetermined wavelength

which carries out induction of the isomerization of an azo polymer to surface 10a of the azo polymer support 10 which is a record medium by predetermined intensity distribution.
[0070] Moreover, the optical element of this invention may consist of bases 12, such as a glass substrate and a plastic plate, and an azo polymer layer 14 formed in this base 12 front face, as shown in drawing 3 (b). Similarly, the irregularity of the predetermined configuration which has either [at least] a refraction function or a diffraction function is formed in surface 14a of the azo polymer layer 14. When such irregularity irradiates the light of the predetermined wavelength which carries out induction of the isomerization of an azo polymer to surface 14a of the azo polymer layer 14 of this record medium by predetermined intensity distribution, the irregularity of a predetermined configuration is formed in surface 14a.
[0071] The record medium equipped with the above-mentioned azo polymer layer 14 is producible by carrying out the cast of the chloroform solution of an azo polymer for example, on the washed base 12, and drying. Moreover, the spin coat of the azo polymer solution may be carried out on a base 12, and the azo polymer layer 14 may be formed. Moreover, when using the film-like base 12, an azo polymer ingredient can be pasted up on a base 12 with a hotpress, and the azo polymer layer 14 can also be formed.
[0072] The above-mentioned irregularity has either a diffraction function or a refraction function with spacing (concavo-convex pitch) in which irregularity is formed. When considering a diffraction function, a concavo-convex pitch is equivalent to a lattice spacing lambda. In the wavelength of incident light, if the refractive index of lambda and a medium is set to n and an angle of diffraction (2 light-wave crossed axes angle of hologram record) is set to theta, a lattice spacing lambda will be given by the following formula.
[0073]
[Equation 1]

$$\Lambda = \frac{\lambda}{2n\,sin\left\{\frac{1}{2}sin^{-1}\left(\frac{1}{n}sin\,\theta\right)\right\}}$$

[0074] For example, if it is the wavelength of lambda= 600nm of incident light, and the refractive index n= 1.5 of a medium (azo polymer), as for an angle of diffraction theta, a lattice spacing lambda will become small with 0 degree - 7 degrees in 5 micrometers or more, and, as for an angle of diffraction theta, a lattice spacing lambda will become large with 90 degrees in 0.5 micrometers. that is, when a concavo-convex pitch is to some extent large, an angle of diffraction mainly has the operation by refraction small, and a concavo-convex pitch becomes narrow -- it is alike, and it follows and comes to have an effective (an angle of diffraction -- large) diffraction function. Although extent of a diffraction function and a refraction function changes also with the wavelength lambda of incident light, and the refractive indexes of an azo polymer somewhat strictly this passage, when a concavo-convex pitch is roughly formed at spacing which is 5-100 micrometers, that irregularity has a refraction function, and when formed at spacing whose concavo-convex pitch is 0.2-5 micrometers, you may think that that irregularity has a diffraction function. Moreover, as for the above-mentioned irregularity, diffraction efficiency changes with the depth (concavo-convex depth) in which irregularity is formed. As aforementioned, generating of zero-order light decreases as the concavo-convex depth becomes deep, and diffraction efficiency improves.
[0075] In addition, a concavo-convex pitch is spacing of adjoining heights and heights, and the concavo-convex depth is the gap of the maximum heights and the maximum crevice. These irregularity pitch and the concavo-convex depth can be measured from the observation image by AFM (atomic force microscope). What is necessary is just to ask for the average or the distributed range like a speckle pattern, when a concavo-convex pitch is not fixed. Moreover, based on the above-mentioned relational expression, it can also ask for a concavo-convex pitch from the refractive index n and angle of diffraction theta of wavelength lambda and an azo polymer of incident light.

[0076] [Gestalt of the 1st operation] The optical element of the gestalt of this operation forms in the front face of azo polymer support the irregularity (the 1st irregularity) which functions as a lenticular lens, and forms in the front face of this irregularity the irregularity (the 2nd irregularity) which has a diffraction function at spacing narrower than this irregularity. In addition, the lenticular lens has the structure shown in drawing 4 (a).
[0077] First, as shown in drawing 5 , the light wave 18 which has light and darkness (optical intensity distribution shown in drawing 6) corresponding to the configuration of a lenticular lens with the space optical modulator 16 is generated, and image formation of this light wave 18 is carried out to surface 10a of the azo polymer support 10 with lenses 20 and 22. Thereby, as shown in drawing 7 (a), irregularity 24 is formed in surface 10a of the azo polymer support 10 so that it may have an operation of a lenticular lens.
[0078] As shown in drawing 7 (a), if incidence of the light (incident light) 26 is carried out, the diffused light 28 can be acquired from the side by which irregularity 24 was formed in the azo polymer support 10 in which this irregularity 24 was formed by the refraction function of irregularity 24. The beam profile of the diffused light 28 is shown in drawing 7 (b). the diffusion property of the lenticular lens shown in drawing 4 (b), and abbreviation -- it turns out that it has the same diffusion property.
[0079] Next, as shown in drawing 8 , it branches to two light waves and a laser beam is irradiated as the body light 30 and a reference beam 32 at surface 10a in which the irregularity 24 of the azo polymer support 10 was formed, respectively. The body light 30 and a reference beam 32 are mutually taken as the circular polarization of light of the circumference of reverse. A surface relief hologram is recorded efficiently by this, and detailed irregularity is formed in the front face of the irregularity 24 of the azo polymer support 10.
[0080] If it designs so that the primary plus light 34, the primary minus light 36, and the zero-order light 38 may be diffracted equally when incident light 26 carries out incidence of the surface relief hologram, as shown in drawing 9 (a) When incidence of the incident light 26 is carried out to the azo polymer support 10 from the side in which irregularity 24 was formed, the diffused light (the primary plus light 34, the primary minus light 36, and zero-order light 38) of trifurcation is generated, and the beam of a diffusion angle shown in drawing 9 (b) can be obtained.
[0081] While the same refraction effectiveness as a lenticular lens is acquired with the irregularity formed in the front face of azo polymer support by the optical element of the gestalt of this operation as above, the diffraction effect can be acquired with the detailed irregularity formed in the front face of this irregularity. Moreover, since both the refraction effectiveness and the diffraction effect are acquired, a complicated beam profile can be obtained according to an application. Furthermore, by irradiating the optical pattern of arbitration and carrying out induction of the irregularity of a request configuration to a front face, irregularity can be formed in a front face and an optical element can be manufactured simple and cheaply.
[0082] [Gestalt of the 2nd operation] It forms an azo polymer layer in the concavo-convex (the 1st irregularity) field of a lenticular lens, and forms the irregularity (the 2nd irregularity) which has a diffraction function at spacing narrower than the irregularity of a lens on the front face of this azo polymer layer further while the lenticular lens which is a dioptrics component as a base is used for the optical element of the gestalt of this operation.
[0083] First, as shown in drawing 10 , the coat of the azo polymer is carried out to homogeneity, and the azo polymer layer 14 is formed in the concave convex of lenticular lens 12A of a quartz. The azo polymer layer 14 is formed along with the irregularity of a lenticular lens 12A front face. This lenticular lens has the structure shown in drawing 4 (a), and as shown in drawing 4 (b), it diffuses incident light so that mesial magnitude full width may become 10 degrees.
[0084] Next, as shown in drawing 11 , it branches to two light waves and a laser beam is irradiated as the body light 30 and a reference beam 32 at surface 14a of the azo polymer layer 14, respectively. The body light 30 and a reference beam 32 are mutually taken as the circular polarization of light of the circumference of reverse. A surface relief hologram is recorded efficiently by this, and detailed irregularity is formed in surface 14a of the azo polymer layer 14.

[0085] If it designs so that the primary plus light 34, the primary minus light 36, and the zero-order light 38 may be diffracted equally when incident light 26 carries out incidence of the surface relief hologram, as shown in drawing 12 (a) When incidence of the incident light 26 is carried out to the azo polymer layer 14 from the side in which irregularity 24 was formed, the diffused light (the primary plus light 34, the primary minus light 36, and zero-order light 38) of trifurcation is generated, and the beam of a diffusion angle shown in drawing 12 (b) can be obtained.
[0086] While the refraction effectiveness is acquired with a lenticular lens by the optical element of the gestalt of this operation as above, the diffraction effect can be acquired with the detailed irregularity formed in the front face of an azo polymer layer. Moreover, since both the refraction effectiveness and the diffraction effect are acquired, a complicated beam profile can be obtained according to an application. Furthermore, by irradiating the optical pattern of arbitration and carrying out induction of the irregularity of a request configuration to a front face, irregularity can be formed in a front face and an optical element can be manufactured simple and cheaply.
[0087] In addition, although the example which uses the lenticular lens of a quartz above was explained, as long as it is insoluble as a dioptrics component to the solvent which dissolves the above-mentioned azo polymer, the thing of what kind of medium may be used, and what kind of forms, such as the spherical surface, the aspheric surface, and a concave lens, are sufficient also as the configuration.
[0088] [Gestalt of the 3rd operation] It forms an azo polymer layer in the concavo-convex (the 1st irregularity) field of a lenticular lens, and forms the irregularity (the 2nd irregularity) which has a refraction function at spacing narrower than the irregularity of a lens on the front face of this azo polymer layer further while the lenticular lens which is a dioptrics component as a base is used for the optical element of the gestalt of this operation.
[0089] First, like the gestalt of the 2nd operation, the coat of the azo polymer is carried out to homogeneity, and the azo polymer layer 14 is formed in the concave convex of lenticular lens 12A of a quartz. The azo polymer layer 14 is formed along with the irregularity of a lenticular lens 12A front face. This lenticular lens has the structure shown in drawing 4 (a), and as shown in drawing 4 (b), it diffuses incident light so that mesial magnitude full width may become 10 degrees.
[0090] Next, the speckle pattern from a diffuser is imprinted to surface 14a of the azo polymer layer 14 using the speckle imprint optical system shown in drawing 13 . That is, the diffused light 50 by which is made to carry out incidence of the laser beam 42 from the light source 40 to a diffuser 48 as the circular polarization of light 46 with the quarter-wave length plate 44, and outgoing radiation is carried out behind a diffuser 48 is irradiated at surface 14a of the azo polymer layer 14. Thereby, as shown in drawing 14 , the irregularity 52 according to a speckle pattern is formed in the azo polymer layer 14.
[0091] The diffusion property of the horizontal and the perpendicular direction of this optical element is shown in drawing 15 . Horizontally it is the direction where the cylindrical side of a lenticular lens is located in a line, and, perpendicularly, is the direction which intersects perpendicularly with this here. A continuous line shows the diffusion property after a speckle pattern imprint, and a dotted line shows the diffusion property before a speckle pattern imprint. The direction of the optical element which formed the irregularity 52 according to a speckle pattern in the azo polymer layer 14 excels [whenever / diffusion angle] in the diffusion property greatly so that drawing 15 may show.
[0092] The more excellent refraction effectiveness can be acquired being able to acquire the refraction effectiveness and pressing down the thickness of a component also with the detailed irregularity formed in the front face of an azo polymer layer, while the refraction effectiveness is acquired with a lenticular lens by the optical element of the gestalt of this operation as above. Moreover, by irradiating the optical pattern of arbitration and carrying out induction of the irregularity of a request configuration to a front face, irregularity can be formed in a front face and an optical element can be manufactured simple and cheaply.
[0093] In addition, although the example which uses the lenticular lens of a quartz above was explained, other dioptrics components may be used like the gestalt of the 2nd operation.
[0094] Moreover, although the example which imprints the speckle pattern obtained from the diffuser above was explained, the light of the intensity distribution corresponding to a computer generated

hologram or kino form is irradiated, and the irregularity according to these intensity distributions can also be formed. A computer generated hologram is a hologram recorded with the light of the intensity distribution which calculate the interference fringe produced by body light and the reference beam, and are equivalent to a count result. A computer generated hologram is explained in full detail in an example. Kino form is reinforcement or not the polarization direction but the hologram which recorded phase distribution.

[0095] When mass-producing the [manufacture approach suitable for mass production method], next the duplicate object of the optical element of this invention, the suitable manufacture approach is explained. The optical element of this invention is characterized by forming in the front face of azo polymer support or an azo polymer layer the irregularity of the predetermined configuration which has either [at least] a refraction function or a diffraction function as above-mentioned. Therefore, the optical element equipped with the shape of same toothing can be reproduced by imprinting the irregularity formed in the front face.

[0096] For example, the metal mold (metal master) of the negative of this optical element is producible by performing electric conduction processing to an optical element by golden vacuum evaporationo or electroless deposition, and performing electrocasting, such as nickel, like the production process of a compact disk, using the optical element which irradiated the optical pattern of arbitration and carried out induction of the irregularity of a request configuration to the front face of azo polymer support or an azo polymer layer. Based on this metal mold, a pattern can be imprinted into resin ingredients, such as an acrylic, Pori Karr Nate, and polyester, and a duplicate object (optical element) can be obtained by thermocompression bonding, injection-molding processing, etc. into them.

[0097] Below, the production process of a duplicate object is explained. First, like the gestalt of the 1st operation, as shown in drawing 16 (A), while irregularity 24 is formed in surface 10a of the azo polymer support 10, the optical element by which detailed irregularity was formed in the front face of irregularity 24 is produced. Next, as shown in drawing 16 (B), gold is vapor-deposited to surface 10a in which the irregularity 24 and the detailed irregularity of this optical element were formed, and the thin film deposit 54 is formed in it (mastering process).

[0098] Next, the metal master 56 which formed the metal master 56 of predetermined thickness by nickel electrocasting on the thin film deposit 54, and was formed by drawing 16 (D) is exfoliated from the thin film deposit 54 in drawing 16 (C). By drawing 16 (E), a mother 58 is formed by nickel electrocasting on this metal master 56 that exfoliated, and a mother 58 is exfoliated from a metal master 56 in drawing 17 (A). By drawing 17 (B), La Stampa 60 is formed by nickel electrocasting on the mother 58 who exfoliated, by drawing 17 (C), it exfoliates from a mother 58 and La Stampa 60 completes La Stampa 60 (La Stampa making process). This La Stampa 60 is equipped with the irregularity corresponding to the irregularity 24 and the detailed irregularity which were formed in surface 10a of the azo polymer support 10.

[0099] Next, as shown in drawing 17 (D), the polyester resin 65 which attached and carried out thermofusion of this La Stampa 60 to the injection molding machine which consists of a cover half 62 and a migration mold 64 is poured in by the high-pressure force from an inlet (not shown), and injection molding is performed. Finally, as shown in drawing 17 (E), the temperature of an injection molding machine falls and the optical element 66 made of polyester resin is taken out in the place which resin hardened. The irregularity of the same configuration as the irregularity 24 and the detailed irregularity which were formed in surface 10a of the azo polymer support 10 is formed in surface 66a of the taken-out optical element 66 (imprint forming cycle).

[0100] By the above-mentioned approach, since La Stampa is produced from an optical element and a duplicate object is manufactured with thermocompression bonding or injection molding using this La Stampa, it is suitable for producing a duplicate object in large quantities.

[0101] As explained above, the optical element of this invention can acquire the outstanding refraction effectiveness and/or the outstanding diffraction effect with the irregularity formed in the front face of the macromolecule layer which consists of an azo polymer. Since it has the function of both a diffraction component and a refraction component in acquiring the diffraction effect especially in addition to the

refraction effectiveness, it is effective in obtaining the beam of the configuration of arbitration, and application of [besides an optical bus system / spectroscope / an image formation optical element, a super resolution lens, / variably] can be expected.
[0102] Moreover, when using the azo polymer near the room temperature which has the desirable glass transition point of an elevated temperature [room temperature], easy and the refraction effectiveness which was excellent while it could form in stability and the degree of freedom of a design improved, and/or the outstanding diffraction effect can be acquired for the irregularity of sufficient depth for the front face of a macromolecule layer.
[0103] Moreover, according to the manufacture approach of the optical element of this invention, by irradiating the optical pattern of arbitration, such as an interference fringe of light, a speckle pattern, and a computer generated hologram, induction of the complicated irregularity can be carried out easily, and an optical element can be produced that it is simple and cheaply. Furthermore, according to the manufacture approach of the optical element duplicate object of this invention, it is also possible to produce La Stampa based on this optical element, and to manufacture a duplicate object in large quantities using La Stampa. Moreover, according to the obtained optical element duplicate object, the outstanding refraction effectiveness and/or the outstanding diffraction effect can be acquired like the optical element of this invention.
[0104] In addition, although the example which prepares above the irregularity which has a refraction function for dioptrics components, such as a lens, and the irregularity which has a diffraction function was explained, the irregularity which has a refraction function in other optical elements, such as a polarizing plate, a wavelength plate, and a reflecting plate, and the irregularity which has a diffraction function can also be prepared.
[0105]
[Example] Next, although an example explains this invention to a detail further, this invention is not limited to the following examples.
(Example 1) This example explains the example which produced the optical element suitable as an optical diffusion branching component used for an optical data bus and a signal processor which are indicated by JP,10-282371,A with reference to drawing 18 and drawing 19 .
[0106] As an azo polymer, the polyester (instantiation compound: azo polymer (2)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (2) is 26.8 degrees C, and is suitable for this invention. This azo polymer (2) was applied to transparence glass substrate 12B by the thickness of 1.5 micrometers, and the record medium equipped with the azo polymer layer 14 was produced.
[0107] While irradiating surface 14a of the azo polymer layer 14 as a body light 30, the space optical modulator 16 having generated the light wave (optical intensity distribution shown in drawing 18 (a)) which spread horizontally using the optical system shown in drawing 18 (b), and condensing this light wave with a lens 70, the parallel reference beam 32 was irradiated by the beam splitter 72 at coincidence. The body light 30 and a reference beam 32 were mutually set as the circular polarization of light of the circumference of reverse. A surface relief hologram is recorded efficiently by this, and detailed irregularity is formed in surface 14a of the azo polymer layer 14. The concavo-convex pitch was 0.8-2.0 micrometers.
[0108] The condition of surface 14a is expanded and shown in drawing 19 . As shown in drawing 19 , induction of the surface relief hologram 1 micrometers or more was carried out for the concavo-convex depth by recording with sufficient exposure energy. Consequently, when incidence of the light was carried out to the obtained optical element, the zero-order diffracted light hardly appeared, but the diffused light of the optical intensity distribution shown in drawing 18 (a) was able to be acquired. Therefore, this optical element is suitable as an optical diffusion branching component for above-mentioned optical data buses.
[0109] (Example 2) This example explains the optical diffusion branching component used suitable for an optical data bus and a signal processor which are indicated by JP,10-282371,A, and its production approach with reference to drawing 20 - drawing 22 .

[0110] As an azo polymer, the polyester (instantiation compound: azo polymer (3)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (3) is 48.5 degrees C, and is suitable for this invention. This azo polymer (3) was applied to transparence glass substrate 12B by the thickness of 8.0 micrometers, and the record medium equipped with the azo polymer layer 14 was produced.
[0111] Drawing 20 is the optical intensity distribution for carrying out induction of the lenticular lens of a random pitch to the front face of an azo polymer layer in 5-100 micrometers. The light wave of the optical intensity distribution shown in drawing 20 was generated using the optical system shown in drawing 5 , and the front face of an azo polymer layer was irradiated. The light wave at this time was set as the circular polarization of light. Irregularity is formed in the front face of an azo polymer layer so that this may have an operation of the above-mentioned lenticular lens.
[0112] The concavo-convex depth shows the surface state of an azo polymer layer to drawing 21 . By recording with sufficient exposure energy, as shown in drawing 21 , induction of the surface relief hologram whose concavo-convex depth is a maximum of 1.2 micrometers was carried out.
[0113] The diffusion property of the horizontal and the perpendicular direction of this optical element is shown in drawing 22 . Horizontally, there is no zero-order transmitted light and the beam has diffused it in homogeneity so that drawing 22 may show. On the other hand, since the beam did not spread perpendicularly, this optical element showed good non-isotropic diffusion. That is, in this example, the dioptrics component which equipped the front face with the shape of toothing of arbitration can be produced easily, and a desired diffusion property can be acquired.
[0114] (Example 3) By this example, a speckle pattern is imprinted on the front face of an azo polymer layer from a diffuser, irregularity is formed in it, and the example which produced the optical element is explained.
[0115] When volume hologram record of the speckle pattern which a diffuser is made to penetrate coherent light and is produced behind a diffuser is carried out, it is known that the hologram itself shows a diffusion property. For example, the hologram diffuser by which the diffusion boundary where a refractive index changes gently using this effectiveness was recorded on JP,4-299303,A is indicated. On the other hand, this example explains how to record not refractive-index change but a speckle pattern on the front face of a direct azo polymer layer as irregularity.
[0116] As an azo polymer, the polyester (instantiation compound: azo polymer (5)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (5) is 37.8 degrees C, and is suitable for this invention. This azo polymer (5) was applied to transparence glass substrate 12B by the thickness of 3.0 micrometers, and the record medium equipped with the azo polymer layer 14 was produced.
[0117] Next, the speckle pattern from a diffuser is imprinted to surface 14a of the azo polymer layer 14 using the speckle imprint optical system shown in drawing 23 . That is, incidence of the laser beam 42 from the light source 40 was carried out to the diffuser 48 as the circular polarization of light 46 with the quarter-wave length plate 44, using 488nm of oscillation lines of an Ar ion laser as the light source 40. The non-isotropic-diffusion object which generates the diffused light of an ellipse as a diffuser 48 was used. The record medium has been arranged behind [5mm] a diffuser 48, and the diffused light 50 by which outgoing radiation is carried out from a diffuser 48 was irradiated at surface 14a of the azo polymer layer 14. The speckle pattern of optical on-the-strength 2.2 W/cm2 was irradiated for 8 hours so that induction of the irregularity might fully be carried out to the azo polymer layer 14. The optical element (diffuser) by which the irregularity according to a speckle pattern was formed by this in surface 14a of the azo polymer layer 14 was obtained.
[0118] The result of having observed the concavo-convex pattern by which induction was carried out to drawing 24 at surface 14a of the azo polymer layer 14 by AFM (atomic force microscope) is shown. The maximum of the concavo-convex depth is about 1 micrometer, and the concavo-convex pitch became the configuration where during 100 micrometers [5 micrometers -] of abbreviation was distributed focusing on 50 micrometers. Thus, the speckle pattern was imprinted by the azo polymer layer 14 as irregularity.

[0119] Next, the diffusion property of this diffuser was evaluated. The diffusion property of the horizontal and the perpendicular direction of this optical element is shown in drawing 25 . As drawing 25 showed, the zero-order transmitted light did not have diffusion of the azo polymer layer 14, and it was non-isotropic diffusion. The diffusion property of this optical element is produced according to the refraction effectiveness by the irregularity formed in the front face.
[0120] Thus, in this example, the optical element (diffuser) which has a refraction function with the irregularity of the front face instead of refractive-index distribution is producible. Furthermore, the irregularity of this optical element can be imprinted mechanically, La Stampa can be produced, and it has the merit that the optical element equipped with the shape of same toothing using this La Stampa can be mass-produced.
[0121] (Example 4) By this example, in order to give the diffraction effect to the optical element of the refraction mold produced in the example 2, still more detailed irregularity is formed in the front face of the irregularity formed in the front face of an azo polymer layer, and the example which produced the optical element is explained.
[0122] Using 488nm of oscillation lines of an Ar ion laser as the light source, on the front face in which the irregularity of the azo polymer layer of the optical element produced in the example 2 was formed, it branches to two light waves and a laser beam is irradiated as body light and a reference beam. Polarization of body light and a reference beam was mutually made into the circular polarization of light of the circumference of reverse with the quarter-wave length plate. The surface relief hologram could be efficiently produced by this polarization arrangement, and 1 micrometer or less and the concavo-convex depth were able to form [the concavo-convex pitch] the detailed irregularity of 200nm or less in the front face of the irregularity formed in the azo polymer layer.
[0123] By adjusting the exposure energy of record light (body light and reference beam), it carried out as [diffract / primary plus light, primary minus light, and zero-order light / equally]. Thereby, as shown in drawing 9 (a), the diffused light of trifurcation is generated. The beam profile of the diffused light in this case is as being shown in drawing 9 (b).
[0124] Thus, in this example, the diffraction effect can be added by adding detailed irregularity to the front face of irregularity equipped with a refraction function. Moreover, in the optical element of this example, since both the refraction effectiveness with a lenticular lens and the diffraction effect by the detailed irregularity formed in the front face of an azo polymer layer are acquired, a complicated beam profile can be obtained according to an application.
[0125] In addition, the diffraction effect can be given by the same approach also about the optical element of the refraction mold produced in the example 3.
[0126] (Example 5) This example explains the example which produced the optical element suitable as an optical diffusion branching component used for an optical data bus and a signal processor which are indicated by JP,10-282371,A with reference to drawing 26 - drawing 28 .
[0127] As an azo polymer, the polyester (instantiation compound: azo polymer (6)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (6) is 33.1 degrees C, and is suitable for this invention.
[0128] First, the chloroform solution of an azo polymer (6) was applied to the concave convex of lenticular lens 12A with the spin coat. Thickness of the azo polymer layer 14 was set to 1 micrometer at this time. The azo polymer layer 14 was formed along with the irregularity of a lenticular lens 12A front face. As a lenticular lens, the lenticular lens of the quartz shown in drawing 4 (a) was used. As shown in drawing 4 (b), as for this lens, mesial magnitude full width diffuses 10 degrees of incident light. Moreover, the pitch of the irregularity of a lenticular lens is 166 micrometers, and the concavo-convex depth is 50 micrometers.
[0129] Next, in order to form in a Top Hat-like beam the diffusion angle of the lenticular lens of the quartz shown in drawing 4 (a), a surface relief hologram is produced using the optical system shown in drawing 27 . First, the space optical modulator 16 generated the light wave of the optical intensity distribution shown in drawing 26 (a). This light wave is beforehand designed so that the diffused light by lenticular lens 12A may be transformed into optical Top Hat-like intensity distribution.

[0130] While irradiating as a body light 30, condensing the generated light wave with a lens 70, the parallel reference beam 32 was irradiated by the beam splitter 72 at coincidence. The body light 30 and a reference beam 32 carried out incidence to surface 14a of the azo polymer layer 14 from surface 14b of the opposite side on the abbreviation same axle. The body light 30 and a reference beam 32 were mutually set as the circular polarization of light of the circumference of reverse. Moreover, exposure energy was adjusted so that the diffraction efficiency of a relief hologram might serve as 50% of abbreviation. A surface relief hologram is recorded by this and detailed irregularity is formed in surface 14a of the azo polymer layer 14. The concavo-convex pitch was 0.5-2.0 micrometers, and the concavo-convex depth was 200nm or less.
[0131] Next, incidence of the light was carried out from the surface 14a side of the azo polymer layer 14, and the hologram was reproduced. That is, among the light which carried out incidence, a half light was diffracted with the surface relief hologram, was refracted with the lenticular lens after that, and was diffused. Moreover, the light of the remaining one half which is not diffracted by the hologram was diffused with the lenticular lens as it was. As shown in drawing 28 , when these two diffused lights were put together, the Top Hat-like diffused light was able to be acquired as a result.
[0132] Thus, at this example, a half light is diffused by the dioptrics component, and the light of the remaining one half is generated with a diffracted-light study component so that the diffused light may be compensated. Therefore, it is suitable as an optical diffusion branching component for above-mentioned optical data buses.
[0133] (Example 6) By this example, a computer generated hologram is imprinted on the front face of an azo polymer layer, irregularity is formed in it, and the example which produced the optical element is explained.
[0134] First, a computer generated hologram is explained. Theoretically, if both complex amplitude of the light in the input screen of a computer generated hologram, i.e., a phase and the real amplitude, is decided, the complex amplitude in the output screen of a computer generated hologram can be decided. Analytical conversion relation can describe the relation of these two complex amplitude, and when both are seldom approaching, it has the relation of the Fourier transform. However, implementation of the component which modulates both a phase and the amplitude is difficult, and it is common that only the amplitude modulates only a phase. In the modulation of only a phase or the amplitude, there is no unique relation between a desired output and a computer generated hologram, and it cannot but depend on a retrieval-optimization technique.
[0135] Gerchberg-Saxton which performs the Fourier transform as the technique of optimization repeatedly until it converges -- there are an approach using the technique of neural networks, such as law and the SHUMIRETTEDDO annealing method, an approach using a genetic algorithm, etc. a pattern simple here -- Gerchberg-Saxton with comparatively quick convergence -- the computer generated hologram was computed using law.
[0136] Drawing 29 (b) is the optical intensity distribution in an output screen, and drawing 29 (a) is a computer generated hologram in the input screen for forming it. The computer generated hologram expresses phase distribution in an input screen, a white part corresponds to phase contrast pi, and the black part supports phase contrast-pi. In this example, an azo polymer is irradiated as a shade image as shows a phase contrast pattern to drawing 29 (b), and induction of the front face is carried out in a bright part. The phase of incident light is modulated according to this relief structure by which induction was carried out. Therefore, it is necessary to carry out induction of the irregularity equal to the phase contrast corresponding to a computer generated hologram.
[0137] Image formation of this computer generated hologram was reduced and carried out to surface 10a of the azo polymer support 10 according to the optical system shown in drawing 5 . As an azo polymer, the polyester (instantiation compound: azo polymer (7)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (7) is 38 degrees C, and is suitable for this invention. The maximum of the concavo-convex depth was about 1 micrometer, and the concavo-convex minimum pitch was about 1 micrometer.
[0138] Thus, the computer generated hologram was imprinted by azo polymer support as irregularity.

The result of having observed the front face of azo polymer support by AFM is shown in drawing 32 . Moreover, incidence of the light is carried out to the obtained optical element, and the result of having evaluated the outgoing radiation light is shown in drawing 30 . In spite of having designed the computer generated hologram to four branching, outgoing radiation light became the light wave of 5 branching with the zero-order diffracted light from drawing 30 . Since induction of the irregularity equivalent to phase contrast pi was not carried out to the front face of azo polymer support, this originates in 100% of diffraction efficiency not having been acquired.
[0139] Next, in order to give a lens property to the obtained optical element, the computer generated hologram irradiated the light-and-darkness image corresponding to the configuration of the lenticular lens shown in drawing 6 on the front face of the azo polymer support imprinted as irregularity. At this time, the optical system shown in drawing 5 was used. Induction of the irregularity was carried out to the azo polymer so that it might have an operation of a lenticular lens by this. The concavo-convex pitch was 10 micrometers. When incidence of the light was carried out to the obtained optical element, the diffused light of 5 branching of a mode profile shown in drawing 31 was able to be acquired.
[0140] (Example 7) This example explains the example which produced the metal master for reproducing an optical element using the optical element produced in the example 3 and the example 6.
[0141] Conductive processing is performed to the front face (correctly an azo polymer layer or the front face of azo polymer support) in which the irregularity of an optical element was formed by vacuum evaporationo or electroless deposition. Next, the metal master which is the metal mold of the negative of an optical element is producible with nickel electrocasting etc. If the metal master by which irregularity was imprinted by the precision can be obtained, the rest can obtain a duplicate object easily by producing La Stampa using this metal master, and imprinting a concavo-convex pattern by thermocompression bonding, injection-molding processing, etc. into resin ingredients, such as an acrylic, Pori Karr Nate, and polyester, using this La Stampa.
[0142] Drawing 33 (a) and (b) are the AFM images on the front face of a metal master produced using the optical element obtained in the example 3. Irregularity performed electroless deposition to the front face of the azo polymer layer by which induction was carried out, and produced after that the metal master which is metal mold by nickel electrocasting. By comparing drawing 33 (a), and (b) and drawing 24 shows that the shape of surface type of an azo polymer layer is correctly imprinted by the metal master.
[0143] Drawing 34 (a) and (c) are the AFM images of the azo polymer layer front face of the optical element obtained in the example 6, and drawing 34 (b) and (d) are the AFM images on the front face of a metal master produced using this. Irregularity gave golden vacuum evaporationo to the front face of the azo polymer layer by which induction was carried out, and produced the metal master by nickel electrocasting after that. Drawing 34 (a) - (d) shows that the shape of surface type of an azo polymer layer is correctly imprinted by the metal master.
[0144] Therefore, even if it is the optical element equipped with complicated irregularity by manufacturing an optical element by the above-mentioned approach using this metal master, that duplicate can be mass-produced to simple and low cost.
[0145] (Example 8) This example explains the example which imprinted the speckle pattern from a diffuser on the front face of the azo polymer layer formed in the front face of a lenticular lens, formed irregularity in it, and produced the optical element.
[0146] As an azo polymer, the polyester (instantiation compound: azo polymer (4)) which has a cyano azobenzene in a side chain was used. The glass transition temperature Tg of this azo polymer (4) is 48.5 degrees C, and is suitable for this invention.
[0147] First, the chloroform solution of an azo polymer (4) was applied to the concave convex of lenticular lens 12A with the spin coat, and the azo polymer layer 14 with a thickness of 3 micrometers was formed. The azo polymer layer 14 was formed along with the irregularity of a lenticular lens 12A front face. As a lenticular lens, the lenticular lens of the quartz shown in drawing 4 (a) was used. As shown in drawing 4 (b), as for this lens, mesial magnitude full width diffuses 10 degrees of incident light. Moreover, the pitch of the irregularity of a lenticular lens is 166 micrometers.

[0148] Next, the speckle pattern from a diffuser is imprinted to surface 14a of the azo polymer layer 14 using the speckle imprint optical system shown in drawing 13 . That is, incidence of the laser beam 42 from the light source 40 was carried out to the diffuser 48 as the circular polarization of light 46 with the quarter-wave length plate 44, using 488nm of oscillation lines of an Ar ion laser as the light source. The non-isotropic-diffusion object which generates the diffused light of an ellipse as a diffuser 48 was used. The record medium equipped with the azo polymer layer 14 behind [5mm] the diffuser 48 has been arranged, and the diffused light 50 by which outgoing radiation is carried out behind a diffuser 48 was irradiated at surface 14a of the azo polymer layer 14. The speckle pattern of optical on-the-strength 2.2 W/cm2 was irradiated for 8 hours so that induction of the irregularity might fully be carried out to surface 14a of the azo polymer layer 14. Thereby, as shown in drawing 14 , the optical element (diffuser) by which the irregularity 52 according to a speckle pattern was formed in the azo polymer layer 14 was obtained. In addition, the maximum of the concavo-convex depth of irregularity 52 is about 1 micrometer, and the concavo-convex pitch became the configuration where it was distributed over the range of 100 micrometers [5 micrometers -] of abbreviation focusing on 50 micrometers.

[0149] The diffusion property of the horizontal and the perpendicular direction of this optical element is shown in drawing 15 . A continuous line shows the diffusion property after a speckle pattern imprint, and a dotted line shows the diffusion property before a speckle pattern imprint. The direction of the optical element which formed the irregularity 52 according to a speckle pattern in the azo polymer layer 14 is excellent in the diffusion property so that drawing 15 may show. That is, the diffusion property improved according to the-like secondary refraction effectiveness by the irregularity 52 formed in the front face of the azo polymer layer 14.

[0150] Moreover, in this example, not refractive-index distribution but the diffusion component by surface irregularity is producible. Therefore, the irregularity on this front face of an optical element is imprinted mechanically, the master diffuser of a negative is produced, and there is a merit that a duplicate object can be mass-produced based on this master diffuser.

[0151]

[Effect of the Invention] The optical element of this invention does so the effectiveness that the outstanding refraction effectiveness or the outstanding diffraction effect can be acquired with the irregularity formed in the front face.

[0152] Moreover, when it constitutes so that it may have the irregularity which has the irregularity and the diffraction function to have a refraction function, the effectiveness that the light beam of the configuration of arbitration can be obtained is done so according to the refraction effectiveness and the diffraction effect.

[0153] Moreover, when the polymeric materials which have glass point relocation of the predetermined range are used, while the degree of freedom of a design improves by forming the irregularity (relief structure) of sufficient depth for a front face, the effectiveness that the outstanding refraction effectiveness and/or the outstanding diffraction effect can be acquired is done so.

[0154] The manufacture approach of the optical element of this invention does so the effectiveness that the optical element by which irregularity was formed in the front face can be manufactured simple and cheaply, by irradiating the optical pattern of arbitration and carrying out induction of the irregularity of a request configuration to a front face.

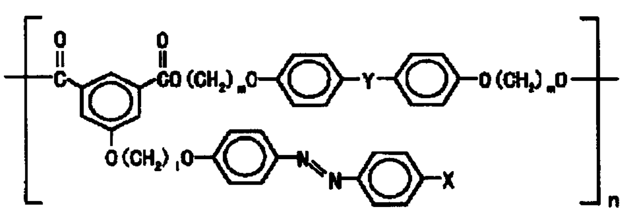
[0155] Since the manufacture approach of the optical element duplicate object of this invention produces La Stampa using the optical element by which irregularity was formed in the front face, it can reproduce easily the optical element of the shape of same surface type, and does so the effectiveness that mass production method becomes possible. Moreover, the obtained optical element duplicate object does so the effectiveness that the outstanding refraction effectiveness and/or the outstanding diffraction effect can be acquired like the optical element of this invention.

[Translation done.]

CLAIMS

[Claim(s)]
[Claim 1] The optical element equipped with the macromolecule layer which has an azobenzene frame by which the irregularity which has a refraction function was formed in the front face of this macromolecule layer.
[Claim 2] The optical element equipped with the macromolecule layer which has an azobenzene frame by which irregularity with a depth of 1 micrometers or more which has a diffraction function was formed in the front face of this macromolecule layer.
[Claim 3] The optical element by which the 2nd irregularity which has a refraction function or a diffraction function was formed in the front face of this 1st irregularity while having the macromolecule layer which has an azobenzene frame and forming in the front face of this macromolecule layer the 1st irregularity which has a refraction function.
[Claim 4] The optical element equipped with a dioptrics component and the macromolecule layer which has the azobenzene frame formed in the front face of this dioptrics component by which the irregularity which has either [at least] a refraction function or a diffraction function was formed in the front face of this macromolecule layer.
[Claim 5] The optical element by which the 2nd irregularity was formed in the front face of this 1st irregularity at spacing narrower than this 1st irregularity while having the macromolecule layer which has an azobenzene frame and forming in the front face of this macromolecule layer the 1st irregularity which has a refraction function.
[Claim 6] The optical element equipped with the dioptrics component equipped with the 1st irregularity which has a refraction function, and the macromolecule layer which has an azobenzene frame on the front face of this 1st irregularity by which the 2nd irregularity was formed in the front face of this macromolecule layer at spacing narrower than said 1st irregularity.
[Claim 7] An optical element given in claim 1 formed at spacing whose irregularity which has said refraction function is 5-100 micrometers, and any 1 term of 3-6.
[Claim 8] An optical element given in any 1 term of claims 2-4 formed at spacing whose irregularity which has said diffraction function is 0.2-5 micrometers.
[Claim 9] An optical element given in any 1 term of claims 1-8 whose glass transition points of said macromolecule are elevated temperatures from a room temperature.
[Claim 10] An optical element given in any 1 term of claims 1-9 whose glass transition points of said macromolecule are near the room temperature.
[Claim 11] An optical element given in any 1 term of claims 1-10 the range of whose glass transition points of said macromolecule is 20 degrees C - 50 degrees C.
[Claim 12] The optical element in which the irregularity to which it has the macromolecule layer which has an azobenzene frame, and the glass transition point of this macromolecule is an elevated temperature from a room temperature, and has either [at least] a refraction function or a diffraction function on the front face of said macromolecule layer was formed.
[Claim 13] The optical element by which it has the macromolecule layer which has an azobenzene

frame, the glass transition point of this macromolecule is near the room temperature, and the irregularity which has either [at least] a refraction function or a diffraction function was formed in the front face of said macromolecule layer.
[Claim 14] The optical element which it has the macromolecule layer which has an azobenzene frame, and is the range whose glass transition point of this macromolecule is 20 degrees C - 50 degrees C and by which the irregularity which has either [at least] a refraction function or a diffraction function was formed in the front face of said macromolecule layer.
[Claim 15] An optical element given in any 1 term of claims 12-14 formed at spacing whose irregularity concerning the part which has a refraction function among said irregularity is 5-100 micrometers.
[Claim 16] An optical element given in any 1 term of claims 12-15 formed at spacing whose irregularity concerning the part which has a diffraction function among said irregularity is 0.2-5 micrometers.
[Claim 17] claim 12- in which the irregularity concerning the part which has a diffraction function among said irregularity was formed in a depth of 1 micrometers or more -- an optical element given in any 1 term of 14 and 16.
[Claim 18] Said irregularity is an optical element given in any 1 term of claims 12-14 equipped with the 1st irregularity which is formed in the front face of said macromolecule layer, and has a refraction function, and the 2nd irregularity which is formed in the front face of this 1st irregularity, and has a refraction function or a diffraction function.
[Claim 19] An optical element given in any 1 term of claims 12-18 by which said macromolecule layer was formed in the front face of a dioptrics component.
[Claim 20] An optical element given in any 1 term of claims 1-19 by which the hologram was recorded on the interior of said macromolecule layer.
[Claim 21] An optical element given in any 1 term of claims 1-20 which set thickness of said macromolecule layer to 1-10 micrometers.
[Claim 22] Said giant molecule is an optical element given in any 1 term of claims 1-21 which contain an azobenzene frame in a side chain.
[Claim 23] Said macromolecule is an optical element given in any 1 term of claims 1-22 which contain an aromatic hydrocarbon radical in a principal chain.
[Claim 24] Said macromolecule is an optical element given in any 1 term of claims 1-23 which are polyester expressed with the following general formula (1).
[Formula 1]
一般式（1）



(Among a formula, X shows a cyano group, a methyl group, a methoxy group, or a nitro group, and Y shows the divalent connection radical by ether linkage, ketone association, or sulfone association.) l and m show the integer of 2-18, and n shows the integer of 5-500.
[Claim 25] The manufacture approach of an optical element of being the manufacture approach of an optical element of manufacturing the optical element of a publication in any 1 term of claims 1-24, irradiating the light which has predetermined intensity distribution, forming the irregularity according to these intensity distribution in the front face of said macromolecule layer, and manufacturing an optical element.
[Claim 26] The manufacture approach of an optical element according to claim 25 that said light is the circular polarization of light.
[Claim 27] The manufacture approach of an optical element according to claim 25 or 26 that said

predetermined intensity distribution are the intensity distribution corresponding to a computer generated hologram or kino form.
[Claim 28] The manufacture approach of an optical element according to claim 25 or 26 that said predetermined intensity distribution are the intensity distribution corresponding to the speckle pattern obtained from the diffuser.
[Claim 29] The manufacture approach of an optical element of being the manufacture approach of an optical element of manufacturing the optical element of a publication in any 1 term of claims 1-24, irradiating body light and a reference beam on the front face of said macromolecule layer, forming the irregularity according to the intensity distribution by the interference light of this body light and a reference beam, and manufacturing an optical element.
[Claim 30] Said body light and reference beam are the manufacture approach of the optical element according to claim 29 which is the circular polarization of light of the circumference of reverse mutually.
[Claim 31] The manufacture approach of an optical element duplicate object of being the manufacture approach of an optical element duplicate object of manufacturing the duplicate object of the optical element of a publication in any 1 term of claims 1-24, producing La Stampa for imprinting this irregularity using the irregularity formed in the front face of said optical element, forming said irregularity and the irregularity of the same configuration in the front face of a resin ingredient, and manufacturing the duplicate object of said optical element with the thermocompression bonding or injection molding using this La Stampa.
[Claim 32] The optical element duplicate object with which the irregularity formed in the front face of an optical element given in any 1 term of claims 1-24 was imprinted.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the diagram showing the DSC curve of an instantiation compound.
[Drawing 2] It is the diagram showing the relation between the relief depth and exposure energy.
[Drawing 3] (a) And (b) is the outline sectional view showing the laminating configuration of the optical element of this invention.
[Drawing 4] (a) is the outline sectional view showing the structure of a lenticular lens, and (b) is the diagram showing the diffusion property of the lens shown in (a).
[Drawing 5] It is an outline sectional view in alignment with the optical axis in which the exposure optical system in the production process of the optical element concerning the gestalt of the 1st operation is shown.
[Drawing 6] It is drawing showing the optical intensity distribution corresponding to the configuration of a lenticular lens.
[Drawing 7] (a) is the outline sectional view showing the phase where coarse irregularity was formed in the production process of the optical element concerning the gestalt of the 1st operation, and (b) is the diagram showing the beam profile of the diffused light of the optical element shown in (a).
[Drawing 8] It is the outline sectional view showing the phase where detailed irregularity was formed in the production process of the optical element concerning the gestalt of the 1st operation.
[Drawing 9] (a) is the outline sectional view showing the diffused light injected from the optical element concerning the gestalt of the 1st operation, and (b) is the diagram showing the beam profile of the diffused light shown in (a).
[Drawing 10] It is the outline sectional view showing the phase where the macromolecule layer was formed in the concave convex of a lens in the production process of the optical element concerning the gestalt of the 2nd operation.
[Drawing 11] It is the outline sectional view showing the phase where detailed irregularity was formed in the macromolecule layer in the production process of the optical element concerning the gestalt of the 2nd operation.
[Drawing 12] (a) is the outline sectional view showing the diffused light injected from the optical element concerning the gestalt of the 2nd operation, and (b) is the diagram showing the beam profile of the diffused light shown in (a).
[Drawing 13] It is an outline sectional view in alignment with the optical axis in which the exposure optical system in the production process of the optical element concerning the gestalt of the 3rd operation is shown.
[Drawing 14] It is the outline sectional view showing the phase where detailed irregularity was formed in the macromolecule layer in the production process of the optical element concerning the gestalt of the 3rd operation.
[Drawing 15] It is the diagram showing the diffusion property of the optical element concerning the gestalt of the 3rd operation.
[Drawing 16] (A) - (E) is the fragmentary sectional view showing the production process of an optical

element.
[Drawing 17] (A) - (E) is the fragmentary sectional view showing the production process of an optical element.
[Drawing 18] (a) is drawing showing the optical intensity distribution used in the example 1, and (b) is an outline sectional view in alignment with the optical axis in which the exposure optical system in the production process of the optical element of an example 1 is shown.
[Drawing 19] It is the enlarged drawing showing the surface state of the optical element of an example 1.
[Drawing 20] It is drawing showing the optical intensity distribution corresponding to the configuration of the lenticular lens of a random pitch used in the example 2.
[Drawing 21] It is the diagram showing the surface state of the optical element of an example 2.
[Drawing 22] It is the diagram showing the diffusion property of the optical element of an example 2.
[Drawing 23] It is an outline sectional view in alignment with the optical axis in which the speckle imprint optical system in the production process of the optical element of an example 3 is shown.
[Drawing 24] It is the perspective view showing signs that the surface state of the optical element of an example 3 was observed by AFM.
[Drawing 25] It is the diagram showing the diffusion property of the optical element of an example 3.
[Drawing 26] (a) is drawing showing the optical intensity distribution used in the example 5, and (b) is the diagram showing the diffusion property of the optical element of an example 5.
[Drawing 27] It is an outline sectional view in alignment with the optical axis in which the exposure optical system in the production process of the optical element of an example 5 is shown.
[Drawing 28] It is the diagram showing the beam profile of the diffused light injected from the optical element of an example 5.
[Drawing 29] (a) is a computer generated hologram in the input screen of the optical element of an example 6, and (b) is the optical intensity distribution in an output screen.
[Drawing 30] It is the diagram showing the beam profile of the diffused light injected from the optical element of an example 6.
[Drawing 31] It is the diagram showing the beam profile of the diffused light injected from the optical element (lens property grant) of an example 6.
[Drawing 32] It is drawing showing signs that the surface state of the optical element of an example 6 was observed by AFM.
[Drawing 33] (a) is the perspective view showing signs that the surface state of the metal master produced using the optical element of an example 3 was observed by AFM, and (b) is the fragmentary sectional view which met the scale of (a).
[Drawing 34] The perspective view showing signs that (a) observed the surface state of the optical element of an example 6 by AFM, the perspective view showing signs that (b) observed the surface state of the metal master produced using the optical element of an example 6 by AFM, the fragmentary sectional view to which (c) met the scale of (a), and (d) are the fragmentary sectional views which met the scale of (b).
[Drawing 35] (a) And (b) is drawing showing the conventional technique of an optical data bus, and (c) is drawing at the time of replacing with the dioptrics component of an optical data bus, and attaching a diffracted-light study component.
[Description of Notations]
10 Azo Polymer Support
10a Front face
12 Base
12A Lenticular lens
14 Azo Polymer Layer
14a Front face
16 Space Optical Modulator
18 Light Wave

20 22 Lens
24 Irregularity
26 Light (Incident Light)
28 Diffused Light
30 Body Light
32 Reference Beam
34 Primary Plus Light
36 Primary Minus Light
38 Zero-order Light
40 Light Source
44 Quarter-wave Length Plate
46 Circular Polarization of Light
48 Diffuser
50 Diffused Light
52 Irregularity
56 Metal Master
58 Mother
60 La Stampa

[Translation done.]

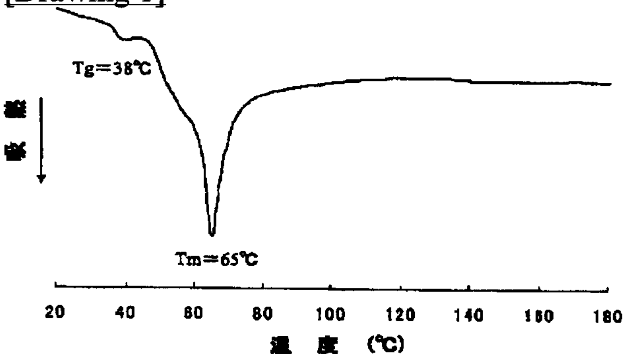
* NOTICES *

JPO and INPIT are not responsible for any damages caused by the use of this translation.

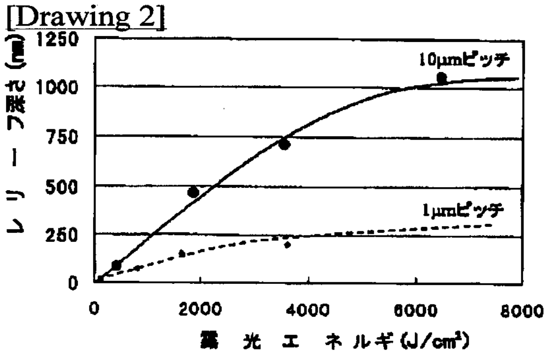
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

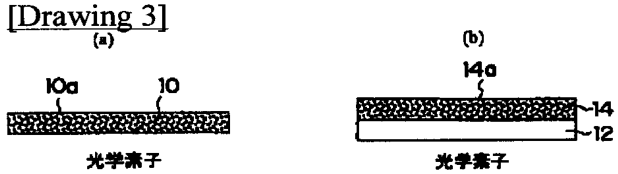
[Drawing 1]



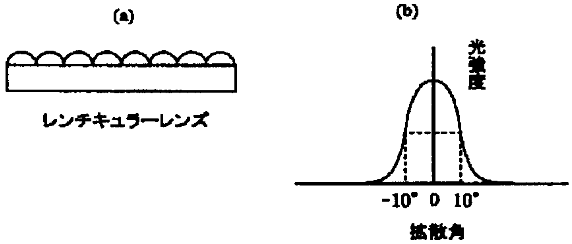
[Drawing 2]



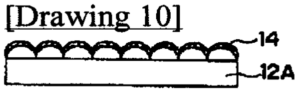
[Drawing 3]



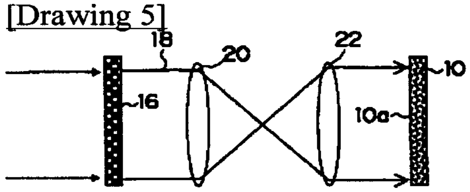
[Drawing 4]



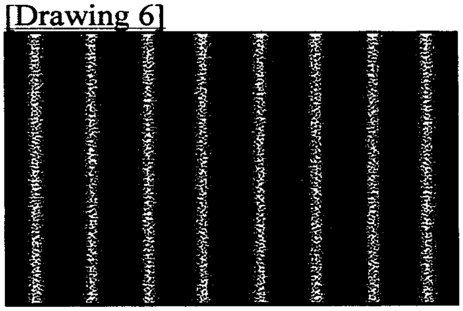
[Drawing 10]



[Drawing 5]

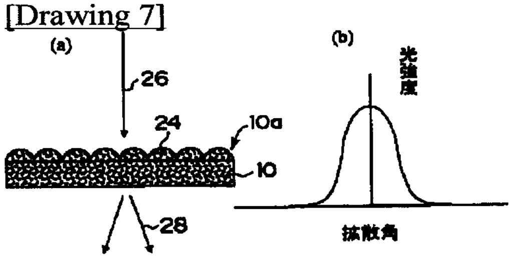


[Drawing 6]

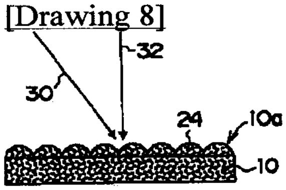


光強度分布の一例

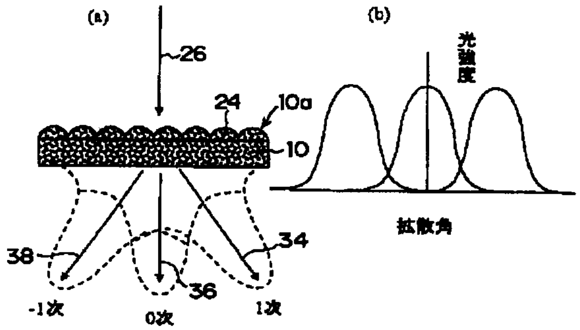
[Drawing 7]



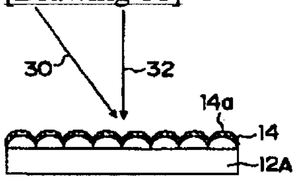
[Drawing 8]



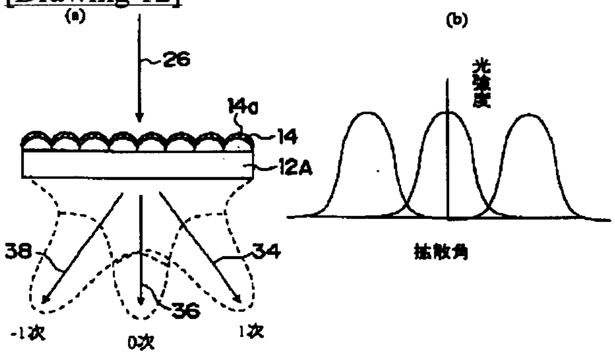
[Drawing 9]



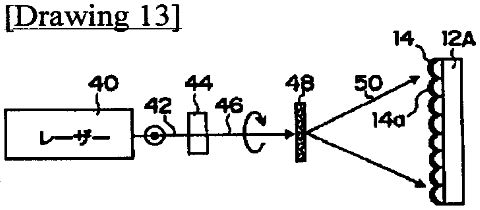
[Drawing 11]



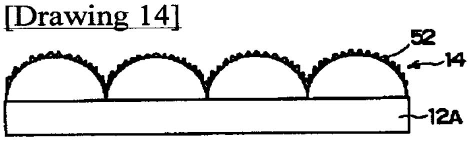
[Drawing 12]



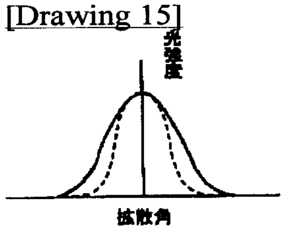
[Drawing 13]



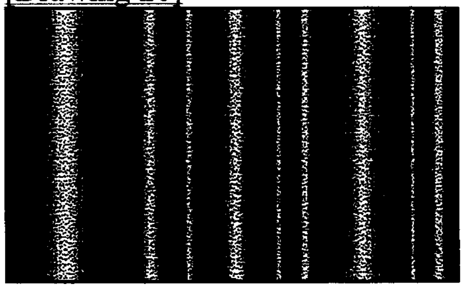
[Drawing 14]



[Drawing 15]

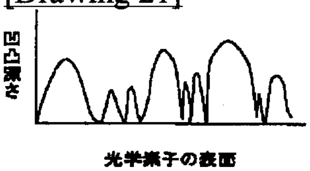


[Drawing 20]

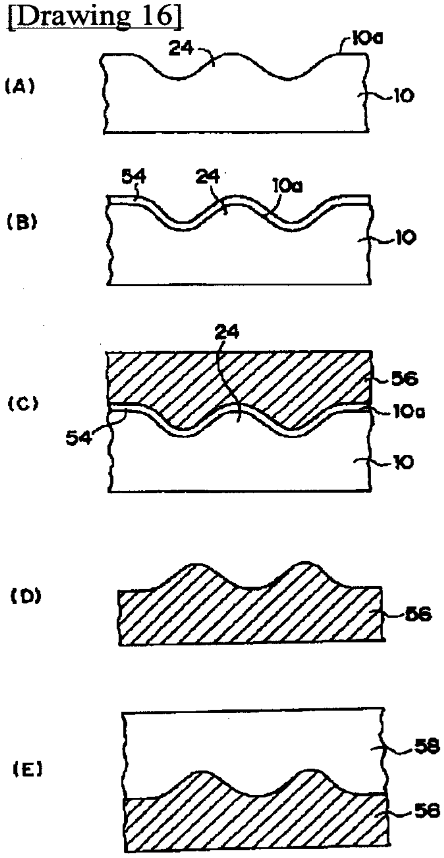


光強度分布の一例

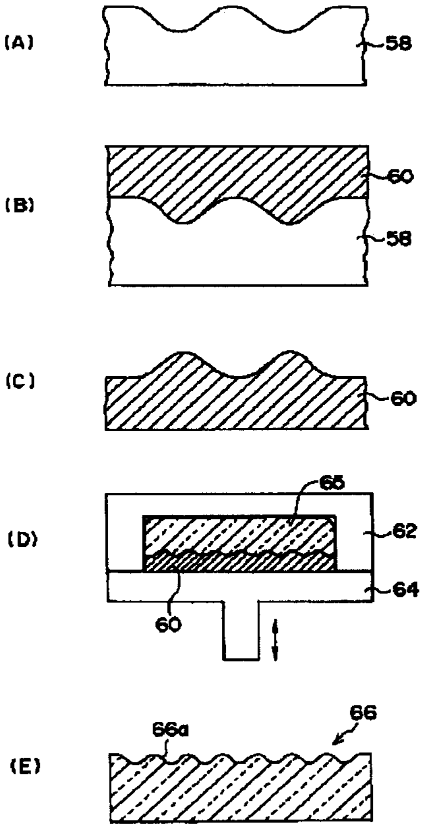
[Drawing 21]



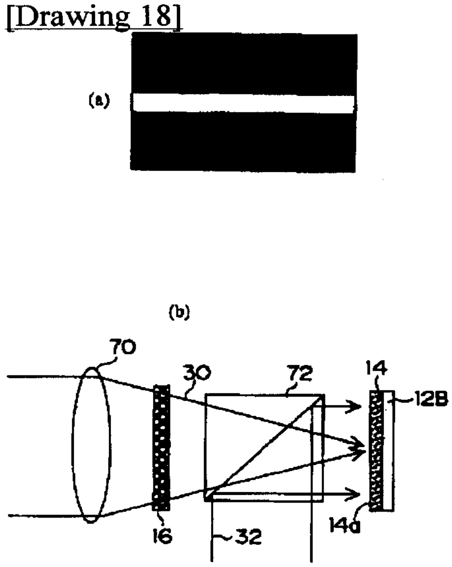
[Drawing 16]



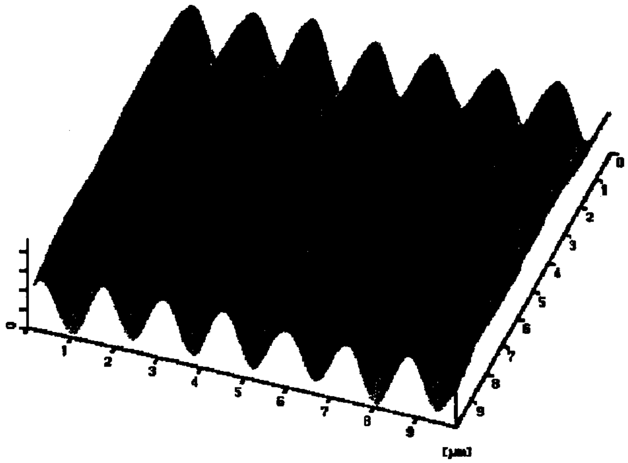
[Drawing 17]



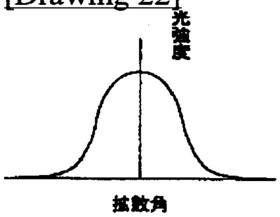
[Drawing 18]



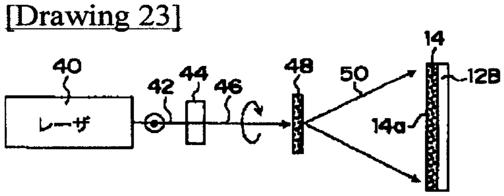
[Drawing 19]



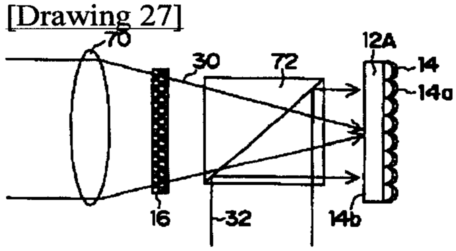
[Drawing 22]



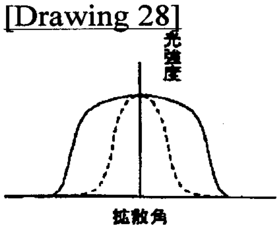
[Drawing 23]



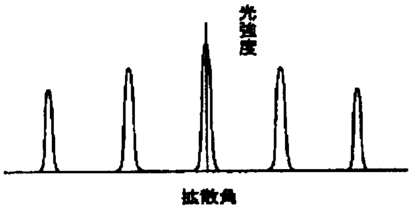
[Drawing 27]



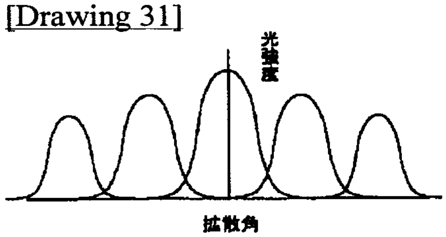
[Drawing 28]



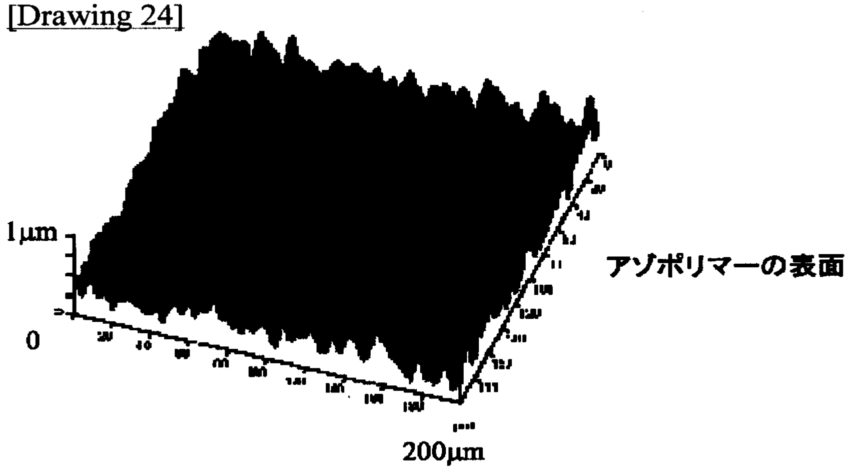
[Drawing 30]



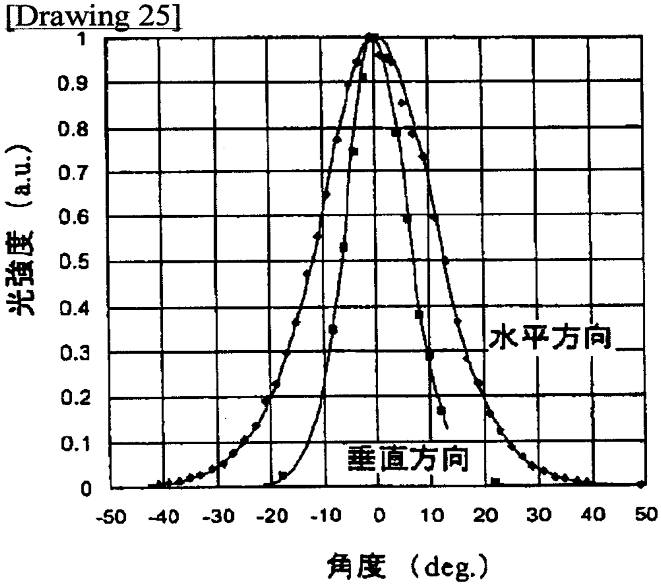
[Drawing 31]



[Drawing 24]



[Drawing 25]

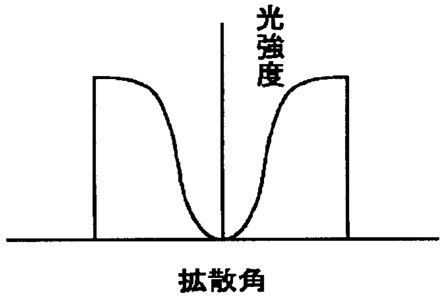


[Drawing 26]

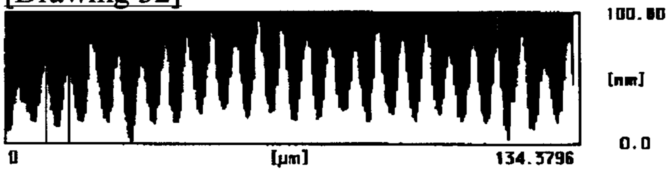
(a)

光強度分布の一例

(b)



[Drawing 32]

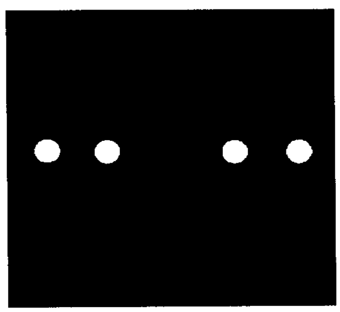


[Drawing 29]

(a)

計算機ホログラム

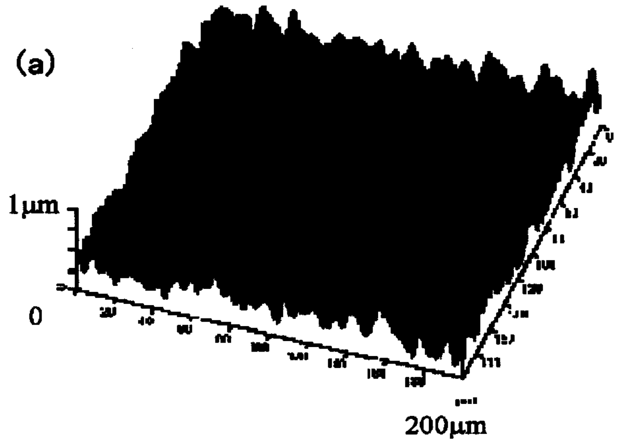
(b)



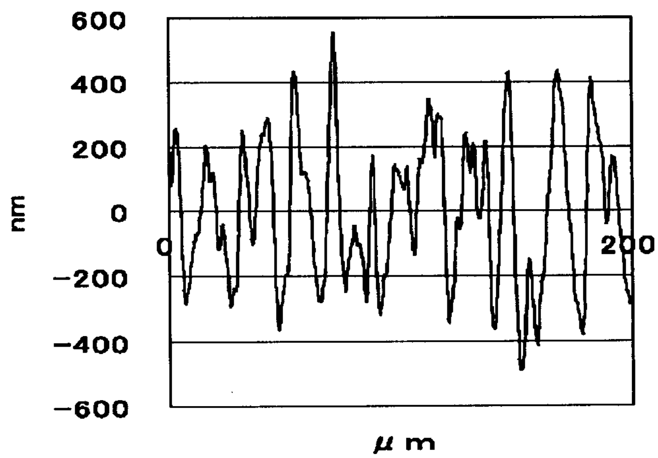
出力パターン

[Drawing 33]

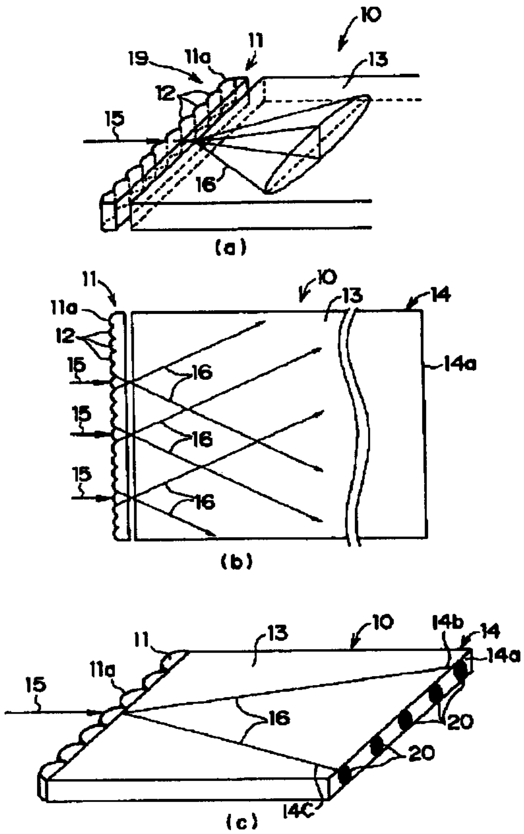
(a)



(b)

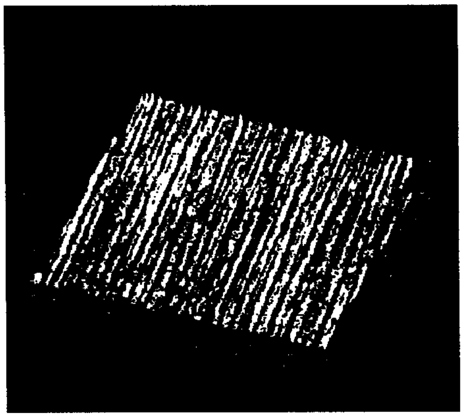


[Drawing 35]

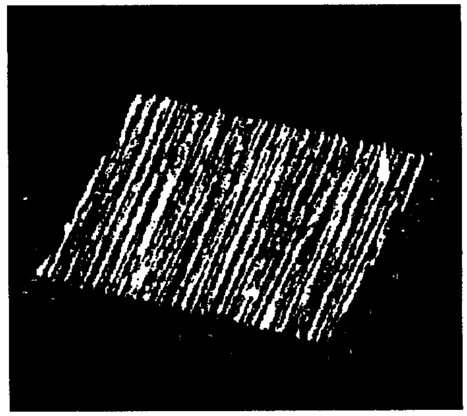


[Drawing 34]

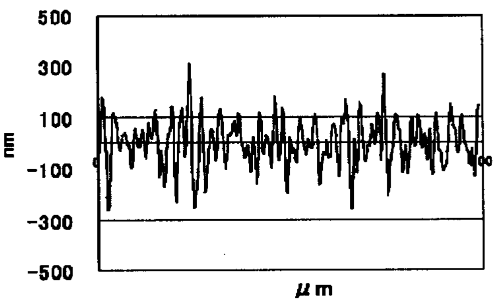
(a) アゾポリマー



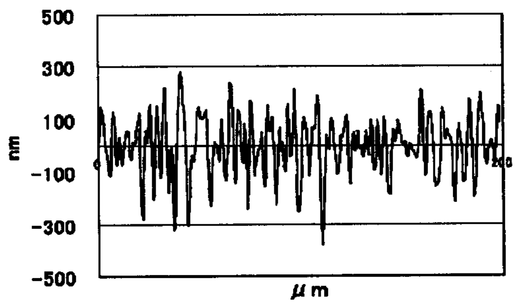
(b)電鋳金型



(c)



(d)



[Translation done.]